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## Energy Optimization Assessments at U.S. Army Installations

Caserma Ederle Vicenza, Italy

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January 2009



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Final Report

Approved for public release; distribution is unlimited.

**Abstract:** An Energy Optimization Assessment was conducted at Caserma Ederle Vicenza, Italy, as a part of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) initiative to identify energy inefficiencies and wastes and propose energy-related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPA) 2005. The study was conducted by the Energy Team, composed of the Construction Engineering Research Laboratory (ERDC-CERL) researchers and their subject matter experts. The scope of the Annex 46 Energy Optimization Assessment included a Level I study of the central energy plants and associated steam distribution systems providing heat to representative administrative buildings, laundry, dining facilities, and other buildings and an analysis of their building envelopes, ventilation air systems, and lighting. The study identified 28 different energy conservation measures (ECMs) that would reduce Caserma Ederle's annual energy use by up to 1,702 MWh/yr in electrical savings, 12,922 MMBtu/yr in thermal energy, and \$37K/yr in maintenance savings for a total of \$769 K/yr of savings.

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# Executive Summary

## General

This work conducted an Energy Optimization Assessment at Caserma Edlerle as a part of the Annex 46 showcase studies to identify energy inefficiencies and wastes and propose energy-related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13423 and Energy Policy Act (EPA) 2005. The study was limited to the Level I assessment. The scope of the study included an analysis of building envelopes, ventilation air systems, controls, interior and exterior lighting, as well as evaluation of opportunities to use renewable energy resources.

The study identified a total of 28 different potential energy conservation measures (ECMs), which are summarized in Table ES1. Table ES2 groups the ECMs into: Building Envelope, Central Energy Plants, Controls, Dining Facilities, heating, ventilating, and air-conditioning (HVAC), Lighting, Miscellaneous, and Renewables. If all these ECMs were implemented, they would result in approximately \$769K savings/yr (1,702 MWh/yr in electrical energy savings, 12,922 MMBtu/yr in thermal savings (mostly fuel oil) in addition to \$37K/yr in maintenance savings). Implementation of these projects would require an additional investment of \$315K and will yield an average simple payback of 0.4 years. A major reason for this relatively small investment requirement is the credit for avoided capitol costs of the central energy plant and distribution systems.

The installation is undergoing many changes, the most significant of which is the demolition of a large portion of the existing facilities and construction of new ones. The detailed schedule that specifies which buildings are to be demolished at what time are included in the installation's Master Plan. This makes energy savings opportunities on the existing facilities difficult. Still, many opportunities were identified that have a very quick payback, and it is recommended that they be pursued. In addition, some facilities are not slated to be demolished until several years in the future. These should be pursued first.

Table ES1. Summary of all ECMs.

ECM #	ECM Description	Electricity Savings		Thermal			Maintenance \$/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint \$/yr	Investment \$	Simple Payback Years
		(MMBtu/yr)	(KWh/yr)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
BE #1	Establish a cool roofs strategy (for all re-roofing projects and for new constructions)	28	8,318	\$1,251	11	\$157		\$1,408		0.0
CEP #1	Thermal storage system	0		\$51,000		\$0		\$51,000	-\$120,000	-2.4
CEP #2	Future district heating system as a hot water system	-512	-150,000	-\$22,566	4,096	\$53,000	\$20,000	\$50,434	-\$1,589,000	-31.5
CON #1	Fix/replace HVAC controls	0		\$0	1,247	\$19,089		\$19,089	\$12,108	0.6
CON #2	Reduce HVAC run time/schedule AHUs to match building occupancy	3,120	914,510	\$137,579	7,706	\$114,217		\$251,795	\$18,000	0.1
CON #3	Consolidate HVAC control systems	0		\$0		\$0		\$0		-
DIN #1	Modify kitchen hoods with end skirts, Bldg 745	140	41,000	\$6,168	235	\$5,266		\$11,434	\$6,000	0.5
DIN #2	Variable flow kitchen hoods	143	42,000	\$6,318	488	\$10,936		\$17,255	\$26,400	1.5
HVAC #1	Shower gray water heat recovery	0		\$0	214	\$3,172		\$3,172	\$15,000	4.7
HVAC #2	Gray water recovery	0		\$0		\$0		\$11,624	\$65,000	5.6
HVAC #3	Replace warm air heating system in vehicle maintenance areas with radiant heating, Bldg 2588	0		\$0	1,000	\$22,410	\$5,000	\$27,410	\$72,000	2.6
HVAC #4	Improved moisture control in Barracks, Bldgs 2102 – 2104, and 2109 – 2111	157	46,000	\$6,920	110	\$2,465	\$10,000	\$19,385	\$153,000	7.9
HVAC #5	Use of variable flow hot and chilled water systems	669	196,000	\$29,486		\$0		\$29,486	\$41,000	1.4
HVAC #6	Enable economizer operation for cooling	308	90,300	\$13,585		\$0		\$13,585	\$10,000	0.7
HVAC #7	Increase/decrease space temperature setpoints and make them uniform	93	27,300	\$4,107	280	\$4,150		\$8,257	\$26,600	3.2
HVAC #8	Local radiator thermostats to prevent overheating,	0		\$0		\$0		\$0	\$26,638	-
HVAC #9	Install heat recovery from refrigeration systems at the Commissary, Bldg 290	0		\$0	1,294	\$19,181		\$19,181	\$36,324	1.9
HVAC #10	Re-commission building controls and replace pneumatic controls with direct digital control (DDC)	0		\$0		\$0		\$0		-
LI #1	Provide light sensors for spaces with natural light	67	19,768	\$3,878		\$0		\$3,878	\$1,000	0.3
LI #2	Solar tubes	102	30,000	\$5,886		\$0	\$2,400	\$8,286	\$42,000	5.1
LI #3	Install occupancy switches in certain spaces	181	53,160	\$10,430		\$0		\$10,430	\$9,444	0.9
MISC #1	Miscellaneous low/no cost							\$6,054	\$6,054	1.0

ECM #	ECM Description	Electricity Savings		Thermal			Maintenance \$/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint \$/yr	Investment \$	Simple Payback Years
		(MMBtu/yr)	(KWh/yr)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
REN #1	Solar wall	0		\$0	337	\$7,552		\$7,552	\$41,000	5.4
REN #2	Photovoltaic Bldgs 1, 2, 3		34,131	\$16,530				\$16,530	\$150,653	9.1
REN #3	Photovoltaic SFEC Building		127,928	\$61,958				\$61,958	\$457,464	7.4
REN #4	Photovoltaic Barracks Bldgs 170, 173		13,321	\$6,452				\$6,452	\$47,597	7.4
REN #5	Photovoltaic Commissary Bldg 290		208,346	\$100,906				\$100,906	\$760,816	7.5
<b>Totals</b>		<b>4,498</b>	<b>1,702,082</b>	<b>439,890</b>	<b>17,017</b>	<b>261,596</b>	<b>37,400</b>	<b>\$768,672</b>	<b>315,097</b>	<b>0.4</b>

Table ES2. Group summary of ECMs.

ECM Category	Report Chapter	Electrical Savings		Thermal		Maintenance \$/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint \$/yr	Investment \$	Simple Payback (yrs)
		KWh/yr	\$/yr	MMBtu/yr	\$/yr				
Building Envelope	3	8,318	\$1,251	11	\$157	\$0	\$1,408	\$0	0.0
Central Energy Plant	4	-150,000	28,434	4,096	53,000	20,000	101,434	-1,709,000	-16.8
Controls	5	914,510	\$137,579	8,953	\$133,306	\$0	\$270,885	\$30,108	0.1
Dining Facilities	6	83,000	\$12,487	723	\$16,202	\$0	\$28,689	\$32,400	1.1
HVAC	7	117,600	\$17,692	2,788	\$48,913	\$5,000	\$83,229	\$251,562	3.0
Lighting	8	102,928	\$20,194	0	\$0	\$2,400	\$22,594	\$52,444	2.3
Miscellaneous	9	0	0	0	0	\$0	\$6,054	\$6,054	1.0
Renewables	10	383,726	\$185,846	337	\$7,552	\$0	\$193,398	\$1,457,530	7.5
<b>Total</b>		<b>1,460,082</b>	<b>\$403,483</b>	<b>16,907</b>	<b>\$259,131</b>	<b>\$27,400</b>	<b>\$707,692</b>	<b>\$121,097</b>	<b>0.2</b>

The **Building Envelope** category contains only one Energy Conservation Measure (ECM), a cool roofs strategy. The specific savings for the buildings at the installation were not documented, but would be approximately 10 to 15 percent of peak cooling demand and can reduce building energy use by up to 50 percent.

The **Central Energy Plant** category consists of two ECMs, installation of a thermal storage system and an alternative for replacement of the heating distribution system. These two projects result in an avoided capital investment cost of approximately \$1.7 million, thermal savings of 4,096 MMBtu/yr, maintenance savings of \$20K/yr. Electrical use would increase by 150MWh/yr due to pumping costs. The combined projects then save a little over \$100K/yr with a reduced investment cost of \$1.7 million.

The **Controls** category consists of three ECMs. They would save 914 MWh/yr in electrical use and 8,953 MMBtu/yr in heating costs for a total of \$271K savings/yr. The investment cost of \$30K results in a quick simple payback of 0.1 years.

The **Dining Facilities** ECM group consists of two ECMs. They would save 83,000 KWh/yr in electrical use and 723 MMBtu/yr for a total of \$29K savings/yr. The investment cost of \$32K results in a simple payback of 1.1 years.

The **HVAC** ECM group consists of 10 ECMs. If all HVAC ECMs were implemented, they would save 117,600 KWh/yr in electrical use and 2,788 MMBtu/yr in thermal savings (mostly fuel oil), and \$5K in maintenance savings resulting in a total of \$667K savings/yr. The investment cost of \$252K results in a simple payback of 3.0 years.

The **Lighting** ECM group consists of three ECMs. If all were implemented, they would save 103 MWh/yr of electrical use, reduce maintenance costs by \$2.4K resulting in total of \$23K savings/yr. The investment cost of \$52 results in a simple payback of 2.3 years.

Five (5) **Renewable** ECMs were identified. If all were implemented, they would save (produce) 384 MWh/yr in electrical use and 337 MMBtu/yr in thermal savings for a total of \$193K savings/yr. The investment cost of \$1.5 million results in a simple payback of 7.5 years. These should be submitted as an FY11 ECIP project.

The Level I analyses of multiple complex systems conducted during the Energy Optimization Assessment are not intended to be (nor should they be) precise. The quantity and quality of the systems improvements identified suggests that significant potential exists.

## **Recommendations**

### **Policy Related Measures**

The cool roofs strategy requires virtually no additional capitol investment. This should be part of the installation design guide.

### **Central Energy Plants**

The two ECMs related to the central energy plants result in \$1.7 million of investment costs and a yearly savings of over \$100K. It is recommended that CEP #2 “Future District Heating System as a Hot Water System” be implemented when the distribution system is replaced. CEP #1 “Thermal Storage System” should also be considered when any changes to the central cooling system are considered. It should also be considered as a measure to reduce the electrical demand since the electrical distribution system is considered to be very close to its capacity.

### **Low to Moderate Cost Projects**

The eight ECMs summarized in Table ES3 were found to have an investment of \$10K or less and result in a simple payback of 1 year or less. All could be implemented as a group for a total of \$32K, save \$47K/yr, and result in a simple payback of just over 6 months. Internal funding (such as SRM) for these projects should be sought.

### **Good Payback and Moderate Investment Projects**

Table ES4 lists ECMs with a simple payback of less than 10 years, but which require moderate investments of between \$10K and \$200K. These 16 ECMs together would have annual savings of \$471K at a cost of \$783K million for a simple payback of 1.7 years. Due to their size and complexity, some may need to be developed further by an Energy Optimization Assessment Level II effort.

Table ES3. ECMs with investment < \$10K and simple payback < 6 years.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
CEP #2	Future district heating system as a hot water system	-150,000	0	\$(22,566)	1,247	\$53,000	\$20,000	\$50,434	\$(1,589,000)	-31.5
CEP #1	Thermal storage system	0	0	\$51,000	4096	\$-	\$-	\$51,000	\$(120,000)	-2.4
BE #1	Establish a Cool Roofs Strategy (for all re-roofing projects and for new constructions)	8,318	0	\$1,251	11	\$157	\$-	\$1,408	\$-	0.0
CON #3	Consolidate HVAC control systems	0	0	\$-	0	\$-	\$-	\$-	\$-	-
HVAC #10	Re-commission building controls and replace pneumatic controls with DDC	0	0	\$-	0	\$-	\$-	\$-	\$-	-
LI #1	Provide light sensors for spaces with natural light	19,768	0	\$3,878	0	\$-	\$-	\$3,878	\$1,000	0.3
DIN #1	Modify Kitchen Hoods with end skirts, Bldg 745	41,000	0	\$6,168	235	\$5,266	\$-	\$11,434	\$6,000	0.5
MISC #1	Miscellaneous low/no cost	0	0	\$-	0	\$-	\$-	\$6,054	\$6,054	1.0
LI #3	Install occupancy switches in certain spaces	53,160	0	\$10,430	0	\$-	\$-	\$10,430	\$9,444	0.9
HVAC #6	Enable economizer operation for cooling	90,300	0	\$13,585	0	\$-	\$-	\$13,585	\$10,000	0.7
<b>Totals</b>		<b>62,546</b>	<b>0</b>	<b>\$12,747</b>	<b>9,588</b>	<b>\$77,913</b>	<b>\$20,000</b>	<b>\$116,313</b>	<b>\$(1,544,394)</b>	<b>-13.3</b>

Table ES4. ECMs with investments between \$10K and \$200K and simple payback of less than 10 years.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		(KWh/yr0	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
HVAC #6	Enable Economizer Operation for Cooling	90,300	0	13,585	0	0	0	13,585	10,000	0.7
CON #1	Fix/Replace HVAC Controls	0	0	0	1,247	19,089	0	19,089	12,108	0.6
HVAC #1	Shower Gray Water Heat Recovery	0	0	0	214	3,172	0	3,172	15,000	4.7
CON #2	Reduce HVAC Run Time/Schedule AHUs To Match Building Occu- pancy	914,510	0	137,579	7,706	114,217	0	251,795	18,000	0.1
DIN #2	Variable Flow Kitchen Hoods	42,000	0	6,318	488	10,936	0	17,255	26,400	1.5
HVAC #7	Increase/Decrease Space Temperature Setpoints and Make Them Uniform	27,300	0	4,107	280	4,150	0	8,257	26,600	3.2
HVAC #8	Local Radiator Thermostats to Prevent Overheating.	0	0	0	0	0	0	12,108	26,638	2.2
HVAC #9	Install Heat Recovery From Refrigeration Systems At The Commissary, Building 290	0	0	0	1,294	19,181	0	19,181	36,324	1.9
HVAC #5	Use of Variable Flow Hot and Chilled Water Systems	196,000	0	29,486	0	0	0	29,486	41,000	1.4
REN #1	Solar Wall	0	0	0	337	7,552	0	7,552	41,000	5.4
LI #2	Solar Tubes	30,000	0	5,886	0	0	0	8,286	42,000	5.1
REN #4	Photovoltaic Barracks Buildings 170, 173	13,321	0	6,452	0	0	0	6,452	47,597	7.4
HVAC #2	Gray Water Recovery	0	0	0	0	0	0	11,624	65,000	5.6
HVAC #3	Replace Warm Air Heating System In Vehicle Maintenance Areas with Radiant Heating, Building 2588	0	0	0	1,000	22,410	0	27,410	72,000	2.6
REN #2	Photovoltaic Bldgs 1, 2, 3	34,131	0	16,530	0	0	0	16,530	150,653	9.1
HVAC #4	Improved Moisture Control in Barracks, Buildings 2102 – 2104 and 2109 - 2111	46,000	0	6,920	110	2,465	37,400	19,385	153,000	7.9
<b>Totals</b>		<b>1,393,562</b>	<b>0</b>	<b>\$226,864</b>	<b>12,676</b>	<b>\$203,173</b>	<b>\$37,400</b>	<b>\$471,168</b>	<b>\$783,319</b>	<b>1.7</b>

## **Good Payback and Significant Investment Projects**

Aside from the central plant ECMs, only a couple of the renewable ECMs require significant investments (over \$200K). Due to their size and complexity, they may need to be developed further by an Energy Optimization Assessment Level II effort, which is geared toward funds appropriation.

## **Level II Analysis Candidates**

Some of the ripest opportunities for savings come from the moderate and high cost ECMs identified. These often require a combination of in-house and outside support.

It is recommended that Caserma Ederle pursue Level II of this Energy Optimization Assessment for Thermal Storage (CEP #1).

## **Thermal Storage**

The rough estimate presented as ECM CEP #1 indicates that a new chilled water plant incorporating a thermal storage tank would be roughly \$120K less than a plant without the thermal storage and the annual electrical cost \$51K less. However, these are rough estimates. The actual pre-design determined in a level II study would determine:

- required cooling load profile based on the types of future buildings and their cooling requirements
- chiller and thermal storage sizing based on required load profile and cooling capacity
- optimal control strategy (when to cool with storage, when to cool with chillers, and when to charge the thermal storage)
- detailed estimates of capital costs of both types of systems (with and without thermal storage)
- detailed estimates of electrical cost savings
- life cycle costs
- economic feasibility of an absorption chiller using waste heat from generators.

## **Photovoltaic**

The potential for photovoltaic (PV) use for electricity generation is good. Estimates presented showed potential for 384 MWh generation/yr, worth \$186K at an estimated investment cost of \$1.4 million. The analysis was thorough; however the following require more in depth analysis:

- investigation of roof structures to ensure the capability of withstanding increased loads and determining the best mechanism for anchoring
- confirmation that the understanding of the rules for payment of PV generated electricity is correct.

Recommendations for the scope of the Level II study can be based on the Level I and demonstration project results. A specific Level II scope could be jointly developed by the CERL and U.S. Army Garrison, Vicenza through review and discussion of results documented in this Level I report. The Level II report will include an analysis that “guesses at nothing – measures everything.” CERL and expert consultants would provide guidance and further assistance in identifying a specific Level II scope of work, respective roles, and the most expeditious implementation path. This will begin with a formal review of this (Level I) report, combined with a planning session to organize the Level II program.

## **New Construction**

Since the majority of the existing buildings at Caserma Ederle will be demolished and rebuilt, significant energy savings potential could be realized with minimal additional investment. The basis for doing this is included in newly published (2007-2008) Design Guides. These design guides achieve at least 30 percent savings over a baseline built to the minimum requirements of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2004. Types of buildings included are barracks (also called Unaccompanied Enlisted Personnel Housing or UEPH), trainee barracks, administrative buildings (e.g., a battalion headquarters, a company operation facility), a maintenance facility, a dining facility, a child development center, and an Army reserve center. The recommendations include insulation levels, window U values, allowed infiltration rates, grey water heat recovery, and dedicated outdoor air systems.

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## Preface

This study was conducted for Caserma Ederle under the Annex 46 program. The technical monitors were Greg Vallery, Chief Engineering Services, Giampaolo Rizzo, Chief, Operations and Maintenance (O&M), and Paul Volkman, Headquarters, Installation Management Command (HQIMCOM).

The work was managed and executed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principal investigators were David Underwood and Alexander Zhivov. Appreciation is owed to David Murr, Director of Public Works Caserma Ederle and his staff for their coordination of the Energy Team and to the Caserma Ederle Directorate of Public Works (DPW) who contributed significantly to the information gathering and feasibility analysis. Dr. Thomas J. Hartranft is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Martin J. Savoie, CEERD-CV-T. The Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. James R. Houston.

## Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
British thermal units (Btu, International Table)	1,055.056	joules
MMBtu	0.293	MWh
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
Feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
Inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles/hr	0.44704	meters/second
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass)/sq ft	9,764.856	kilograms/m <sup>2</sup>
Yards	0.9144	meters

# **1 Introduction**

## **Background**

The Installation Management Command (IMCOM) funded an Annex 46 energy assessment initiative to visit various Army installations to identify and initiate energy-related projects that could enable the installations to better meet the energy reduction requirements mandated by Executive Order 13243, EISA 2007, Energy Policy Act (EPAct) 1992, and EPAct 2005. One of the initiative's most important goals is to assist the installations not only in determining the projects, but also in determining applicable funding and execution methods.

## **Objectives**

The objectives of this study were to identify energy inefficiencies and wastes at Caserma Ederle and propose energy-related projects with applicable funding and execution methods that could enable the installations to better meet the energy reduction requirements mandated by Executive Order 13123 and EPAct 2005.

## **Approach**

### **General overall process**

Overall, the project team performed the following steps:

1. Make an initial site visit to among other items determine the Site's major energy issues and familiarize the Engineering Energy Analysis Program (EEAP) team with installation and operations
2. Assemble a team of SMEs with expertise in technical areas relating to those identified in the initial site visit
3. Make a Technical Assessment visit with the SMEs to make building specific Energy Conservation Measure (ECM) evaluations
4. Analyze Findings and Developed Implementation Strategies.

## **EEAP project team and summary of activities**

### *Private contractors*

Private contractors with various areas of technical expertise were a vital part of the Energy Team. Since Caserma Ederle has an aging central heating plant and distribution system, an expert on central plants and in particular system conversions from steam to hot water was brought into the team. Also of particular interest were renewables so an expert in photovoltaics also visited the installation. Other experts in HVAC, building envelope, and lighting rounded out the contractor portion of the team.

### *ERDC-CERL*

ERDC/CERL implemented an Energy Assessment methodology, which was previously developed as part of the “Industrial Process Modeling and Optimization” program under the auspices of the IEA ECBCS Programme Annex 46 “Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo).” The protocol is designed to assist energy managers and Regional Energy Managers to develop energy conservation projects (self-help for energy managers).

## **Energy Assessment Protocol**

This study was conducted using an Energy Assessment Protocol developed by CERL in collaboration with a team of government, institutional, and private sector parties as a part of the IEA ECBCS Program Annex 46 [<https://kd.erd.c.usace.army.mil/projects/ecbcs/>]. This protocol is based on the analysis of information available from the literature, training materials, the documented and non-documented practical experiences of contributors, and previous successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities.

The Energy Assessment Protocol addresses technical and non-technical organizational capabilities required to make a successful assessment geared to identifying energy and other operating costs reduction measures without adversely impacting Indoor Air Quality, product quality, or (in the case of repair facilities) safety and morale.

A critical element for energy assessment is a capability to apply a “holistic” approach to the energy sources and sinks in the audited target (installation, building, system, and their elements). The holistic approach suggested by the protocol includes the analysis of opportunities related to the energy generation process and distribution systems, building envelope, lighting, internal loads, HVAC, and other mechanical and energy systems. A useful way of visualizing the energy flows within a facility or process is the Sankey diagram (Figures 1 and 2).

The Protocol addresses several different scopes (building stock, individual building, system, and component) and levels of assessment. It distinguishes between the pre-assessment phase (Level 0: selection of objects for Energy Assessments and required composition of the audit team) and three levels of energy audits with differing degrees of rigor. Each of these three levels may be implemented in different ways: simplified or more detailed assessments, depending on the availability of energy consumption information and other data.

During the selection phase, one can choose from a building stock those facilities that have the most promising energy saving potential. Similarly, one can select from a specific building the systems to be audited or, from a system, the components to be considered for more detailed analysis.

The scope and depth of the assessments differ in their objectives, methodologies, procedures, required instrumentation, and approximate duration (Figure 3).

#### *Level I audit*

A *Level I* audit (qualitative analysis) is a preliminary energy and process optimization opportunity analysis consisting primarily of a walk-through review to analyze and benchmark existing documents and consumption figures. The Level I audit takes from 2 to 5 days, and identifies the bottom-line dollar potential of energy conservation and process improvements. No engineering measurements using test instrumentation are made. If the consumption figures are not available (e.g., due to the absence of metering), which is typical for many industrial facilities and manufacturing processes, the Level I audit can be based on analyses and estimates by experienced auditors.

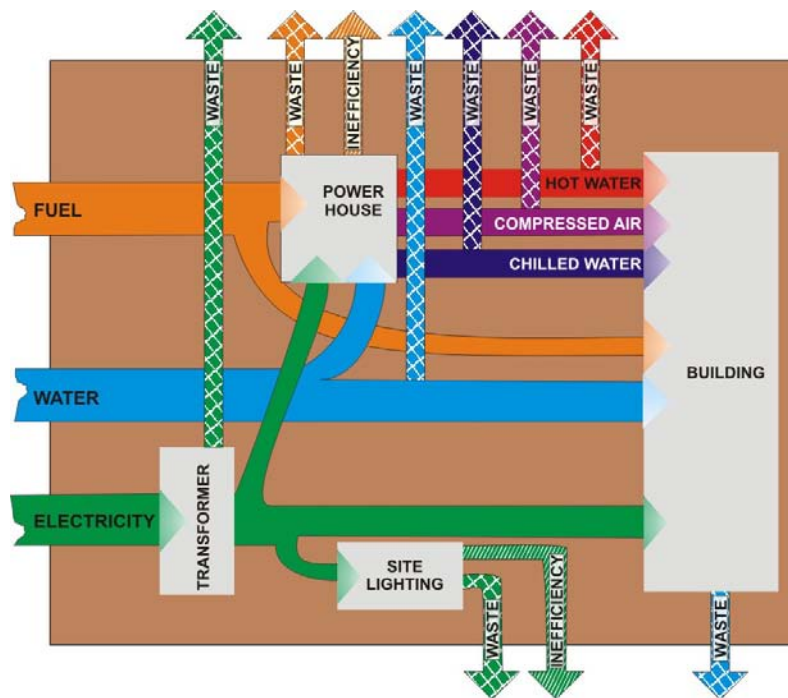


Figure 1. Example Sankey diagram of energy usage, waste, and inefficiencies for an Army installation.

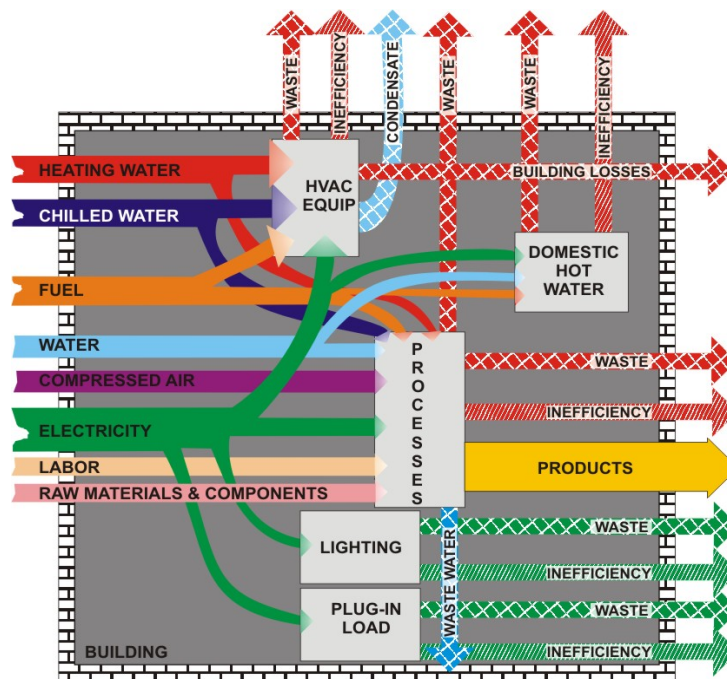


Figure 2. Example Sankey diagram of energy usage, waste, and inefficiencies for a building with production process.



Figure 3. Scope and depth of assessment levels.

A Level I audit would normally recommend that the installation perform some metering, which could be followed by a Level II audit to verify the Level I assumptions, and to more fully develop the ideas from the Level I screening analysis.

#### *Level II audit*

A *Level II* audit (quantitative analysis) includes an analysis geared towards funds appropriation; this analysis uses calculated savings and partial instrumentation measurements with a cursory level of analysis. The Level II study typically takes 5 to 10 times the effort of a Level I, and could be accomplished over a 2- to 6-month period, depending on the scope of the effort. The Level II effort includes an in-depth analysis in which the most crucial assumptions are verified. The end product will be a group of “appropriation grade” energy and process improvement projects for funding and implementation.

### *Level III audit*

Finally, the *Level III* audit (continuous commissioning) is a detailed engineering analysis with implementation, performance measurement and verification (M&V) assessment, and fully instrumented diagnostic measurements (long term measurements). This level takes 3 to 18 months to accomplish. For Energy Savings Performance Contract (ESPC) projects, the *Level III* audit is prolonged until the end of the contract to guarantee that all installed systems and their components operate correctly over their useful lifetimes.

### *Keys to a successful audit*

The key elements that guarantee success of the Energy Assessment are:

- Involvement of key facility personnel and their on-site contractors who know what the major problems are, where they are, and have already thought of many potential solutions;
- The facility personnel's sense of "ownership" of the ideas, which encourages a commitment to successful implementation; and
- A focus on site-specific, critical cost issues. If solved, the greatest possible economic contribution to a facility's bottom line will be realized. Major potential cost issues can include: facility utilization (bottle-necks), mission, labor (productivity, planning, and scheduling), energy (steam, electricity, compressed air), waste (air, water, solid, hazardous), equipment (outdated or state-of-the-art).

From a strictly cost perspective, process capacity and labor utilization/productivity and soldiers' well-being can be far more significant than energy and environmental concerns. All of these issues, however, must be considered together to accomplish the facility's mission in the most efficient and cost-effective way.

## **Scope**

The scope of this Annex 46 Energy Optimization Assessment included a Level I study of the central energy plant and associated steam distribution system providing heat to representative administrative buildings, warehouses and small repair shops; and an analysis of their building envelopes, HVAC systems, photovoltaic, and lighting.

## Mode of technology transfer

The results of this work will be presented to IMCOM, ACSIM and Caserma Ederle for their consideration for implementation and funding and as the basis for other currently conducted studies related to planning for a new central energy plant and utilization of renewable energy sources. It is anticipated that the results of this work will contribute to an enhanced awareness within the Installation Management Command (IMCOM), the U.S. Army Corps of Engineers and its districts, and other Army organizations of opportunities to improve the overall energy efficiency of Army installations. This information will be disseminated through workshops, presentations, and professional industrial energy technology conferences. This report will also be made accessible through the World Wide Web (WWW) at: <http://www.cecer.Army.mil>

## 2 Installation Energy Use Rates

### Utility rates and consumption

Table 1 lists the types of energy and costs incurred by the installation, as reported by in the Army Energy and Water Reporting System (AEWRS).

Table 1. Installation energy use and costs.

Fuel Type	Use	Cost
Electricity	28,351 MWh	\$3.5 million
Fuel oil	17,249 BBLS	\$1.4 million
Natural gas	13,520 KCF	\$151K
Propane	22,299 Gallons	\$78K

### Anticipated future energy costs

Table 2 lists the anticipated future energy costs, as provided by the installation.

Table 2. Anticipated installation energy costs.

Fuel	Cost	Unit	Cost	Unit	Cost	Unit
Gas	0	\$/m <sup>3</sup>	0.00	\$/MMBtu	0.00	E/MMBtu
Electric Low M-Sat (23:00 – 0700) Sunday (all day)	117.1	\$/MWh	34.31	\$/MMBtu	41.54	E/MMBtu
Electric Med M-F (0700-0800) M-F (1900-2300) Sat (0700-2300)	147.6	\$/MWh	43.25	\$/MMBtu	52.36	E/MMBtu
Electric High M-F (0800-1900)	196.2	\$/MWh	57.49	\$/MMBtu	69.60	E/MMBtu
Average electric for constant use	150.44	\$/MWh	44.08	\$/MMBtu	53.37	E/MMBtu
Fuel oil	0.00	\$/gal	0.00	\$/MMBtu	0.00	E/MMBtu
<b>Assumptions</b>						
Fuel oil and gas efficiency	0.85	%				
Exchange rate	0.8259	E/\$				
Fuel oil heat content	139400	cu ft, m <sup>3</sup>				
Gas heat content	1000	Btu/cu ft				

### **3 Building Envelope (BE)**

The survey did not concentrate on building envelopes because it was believed that other areas held more promising opportunities. However, one strategy that is recommended for new construction is “Cool Roofs.”

#### **BE #1. Establish a cool roofs strategy (for all re-roofing projects and for new construction)**

##### **Existing conditions/problems**

Currently many roofs at Ederle Caserma are dark in color. The dark color will absorb the sun’s energy making the roof hotter than the outdoor air temperature. This is also the case with white or close-to-white roofs that do not have cool roof surfaces.

##### **Cool roofs**

People who live in tropical climates usually wear light-colored or white clothing to help keep themselves cool. They know that light colors reflect heat and sunlight, whereas dark colors absorb heat and light. Buildings are similar; buildings with dark-colored roofs will be hotter than buildings with light-colored roofs.

Cool Roofs are roofs consisting of materials that very effectively reflect the sun’s energy from the roof surface. Cool materials for low-slope roofs are mainly bright white in color, although non-white colors are starting to become available for sloped roof applications. Cool Roofs must also have high emissivity, allowing them to emit infrared energy. Unfortunately bare metals and metallic coatings tend to have low emissivity and are not considered cool materials.

Cool roofs reduce the roof surface temperature by up to 100 °F, thereby reducing the heat transferred into the building shown in Figure 4 and 5. This helps reduce energy costs (by keeping attics and ducts cooler), improve occupant comfort, cut maintenance costs, and increase the life cycle of the roof.

Some benefits of Cool Roofs are that they can:

- save on annual electricity bills by reducing summer air-conditioning (AC) costs
- save peak electricity demand costs if used in conjunction with time-of-use metering
- reduce roof maintenance and replacement expenses by extending roof life
- increase indoor comfort in summer by reflecting heat from the roof surface.

Figures 4 and 5 show temperature measurements from other installations on a hot summer day, before and after a cool roof treatment installation.



Figure 4. Roof before treatment, thermometer reads 178 °F at the roof surface on a hot summer afternoon.

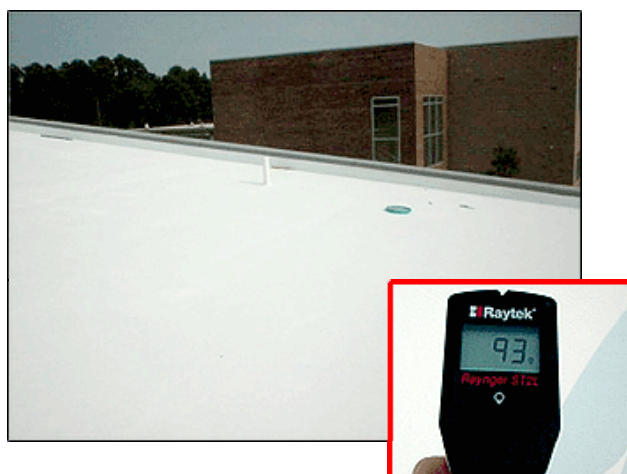


Figure 5. After a cool roof was installed, there was a dramatic decrease in roof air temperature.



Figure 6. The roof of Bldg 108, where a cool roof would make a great difference.

Some examples of hot roofs from Vicenza are the roofs on Bldgs 311, 108, and 302. Figure 6 shows Bldg 108, where a cool roof would make a great difference.

Products for low-slope roofs, found on commercial and industrial buildings, fall into two categories — single-ply materials and coatings. Single-ply materials are large sheets of pre-made roofing that are mechanically fastened over the existing roof and sealed at the Seams. Coatings are applied using rollers, sprays, or brushes, over an existing clean, leak-free roof surface.

Products for sloped roofs, usually found on residences, are currently available in clay, or concrete tiles. These products stay cooler by the use of special pigments that reflect the sun's infrared heat. Lower priced shingles or coated metal roofing products are not yet available in "cool" versions. Visit the ENERGY STAR® Website for a list of cool roof products and manufacturers. [www.energystar.gov](http://www.energystar.gov)

If a cool roof were used, much of the sun's energy will be reflected keeping the roof cooler. This will in turn reduce the cooling energy required to

maintain building temperatures in the summer. A slightly larger amount of energy will be required for heating, but in the climate of Vicenza the cooling savings outweighs the extra heating energy costs.

#### Solution

Whenever replacing a building's roof, provide an outer surface that is categorized as a "Cool Roof." This will reflect the solar energy, resulting in a cooler roof temperature, thus using less energy in air-conditioned spaces. Otherwise, without AC, the comfort in the building will be much improved. Incorporate the Cool Roof requirements into the Installation Design Guide.

#### Savings

ENERGY STAR® qualified roof products save money and energy by reducing the amount of AC needed to keep a building comfortable. ENERGY STAR® qualified reflective roof products can reduce peak cooling demand by 10 to 15 percent and can reduce building energy use by up to 50 percent.

Exact energy and money savings will depend on a number of factors, such as the type and efficiency of insulation in the ceilings and exterior walls, windows, the efficiency of your cooling system, and (most importantly) the climate of the building's location.

Using the ENERGY STAR® Roofing Calculator for Vicenza conditions (actually Baltimore MD was chosen, with heating and cooling degree-days similar to Vicenza Italy) showed the following for a 10,000 sq ft roof:

- office building, air-conditioned, used 7 days/wk.
- existing dark roof: Bitumen, white granular, reflectance 0.25
- ENERGY STAR® labeled roof: Membrane, white, reflectance 0.75
- electricity savings: 8,318 kilowatt hour (kWh)/year worth €1,035
- natural gas: 106 therms worth \$157
- net savings: €840/yr/10,000 sq ft.

For a total roof area of 1 million sq ft the annual net savings will be €84,000.

There are no cost savings in buildings with no AC, but the cool roof will make them cooler in the summer.

#### *Investments*

Initial material costs are comparable with traditional roofing materials - some cool products cost less than traditional materials, some cost up to 20 percent more. Cool protective coatings can be reapplied repeatedly every 10 to 15 years and reduce, if not eliminate the need for expensive roof tear-offs. Combining these maintenance savings with an average 20 percent savings on AC costs make cool roofing a better bargain over the long term.

#### *Payback*

Simple payback will occur within 1 summer month.

## 4 Energy Plants (CEP)

Caserma Ederle has one central plant, described in ECM CEP #2. In addition to looking at the planned renovation of the central plant, this study analyzed the potential for a thermal storage system.

### CEP #1. Thermal storage system

#### Existing condition

The new buildings to be constructed at Dal Molin and Vicenza will have a significant cooling demand. There are plans to build a central chilled water system to service these buildings. There is also a concern that the electrical demand at Vicenza will exceed the current capacity of the electrical distribution system. New diesel-powered generators are being proposed to help satisfy the proposed electrical demand.

A review of the electrical rates indicates that it is far more expensive to use electricity during the day as opposed at night. While the cost savings of electrical use at night verses day use is a benefit, the major benefits are the significant avoided costs of smaller or less chillers and the reduction in the required peak electrical demand.

#### Solutions

A thermal storage system is one of the few methods that can take advantage of low electrical costs at night (off peak rates) and apply the benefits to offset energy that would be consumed to satisfy daytime functions, thereby reducing electrical usage when peak rates apply. A properly designed thermal storage system can also reduce the installed cost of a chilled water cooling system by avoiding the cost of chiller capacity that would be required for the peak cooling load. So rather than purchasing a group of chillers that can produce cooling for the peak load—for example instead of four 750-ton chillers to satisfy a peak load of 3,000 tons—three chillers of approximately 600 tons each plus a large thermal storage tank (500,000 gal or 1,900 m<sup>3</sup>) will provide the desire cooling for the building load. The three 600-ton chillers would run most of the time either sending chilled water to cool the buildings during the day or at night, putting

chilled water into the storage tank for later use. The cost of three 600-ton chillers, cooling towers, pumps, and piping plus the 500,000 gal (1,900 m<sup>3</sup>) tank is less than the cost of four 750-ton chillers, cooling towers, pumps, and piping. The result is a lower cost system that provides a lower cost service.

The sizing of the chiller/thermal storage system depends on the load profile. The cooling demand for a mix of administrative, service, and housing units will peak in the afternoon. The demand will drop off as night approaches since the solar load disappears. At approximately 11 p.m., the load will approach its lowest level, which will normally last until the morning hours of 6 a.m. At this time the load will increase as the housing occupants awake, offices and service facilities open, the sun rises and the temperature of the day increases. The excess cooling water that was generated at night and storage must be large enough to supplement the amount of chilled water provided by the chillers running to satisfy the building cooling loads throughout the day.

Figures 7 and 8 provide a representation of this cooling cycle. The first Figure shows an example of the site's cooling load with the peak cooling requirement at 1500 hrs (3:00 p.m.) and the minimum of cooling demand from 2200 hrs to 600 hrs (10:00 p.m. to 6:00 a.m.). The actual load will need to be determined as part of the building design. The straight line at 1600 tons is the amount of cooling generated by the chillers under the thermal storage approach. At night the excess cooling generated is placed in storage. After 900 hrs (9:00 a.m.) cooling will be withdrawn from the chilled water tank and used to cool the buildings.

The situation at the new facilities proposed for the garrisons at Dal Molin and Vicenza appear to be ideal for a thermal storage application. New central energy plants will be constructed at both locations, which will allow the cost of the storage system to offset chiller costs, thereby providing a net savings. The electrical rates favor thermal storage since the off peak rate is 44 percent of the peak rate (\$117.3 /mWh vs. \$196.2 /mWh). The off peak time period is 11 p.m. at night till 7 a.m., which responds to the time when building cooling loads are at their lowest level.

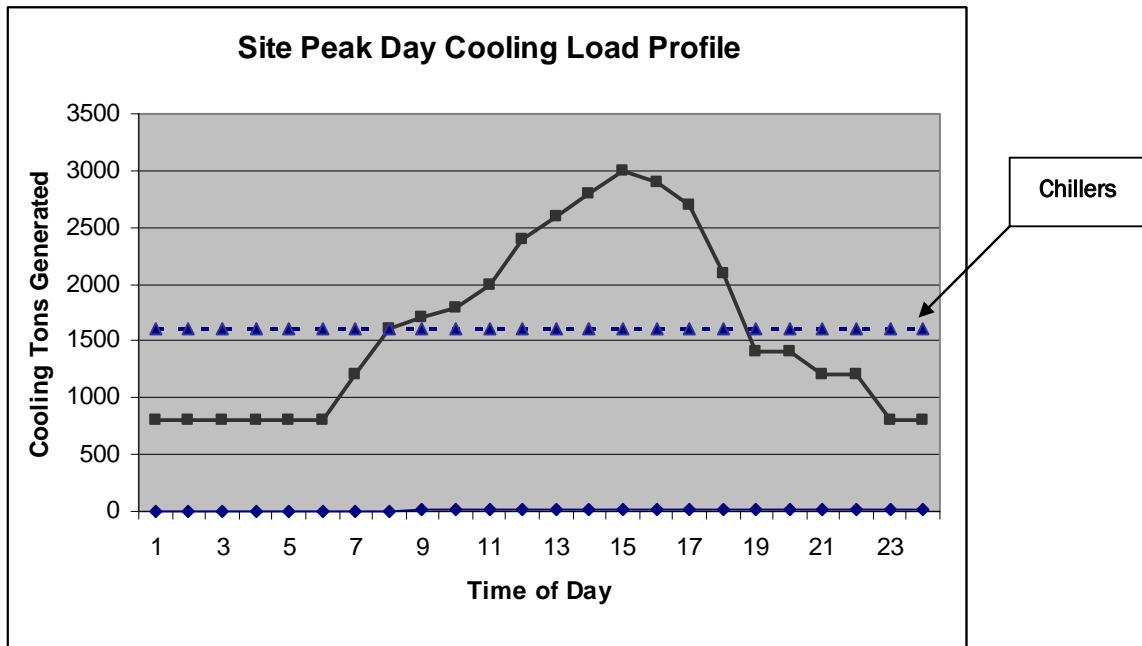


Figure 7. Site peak day cooling load profile.

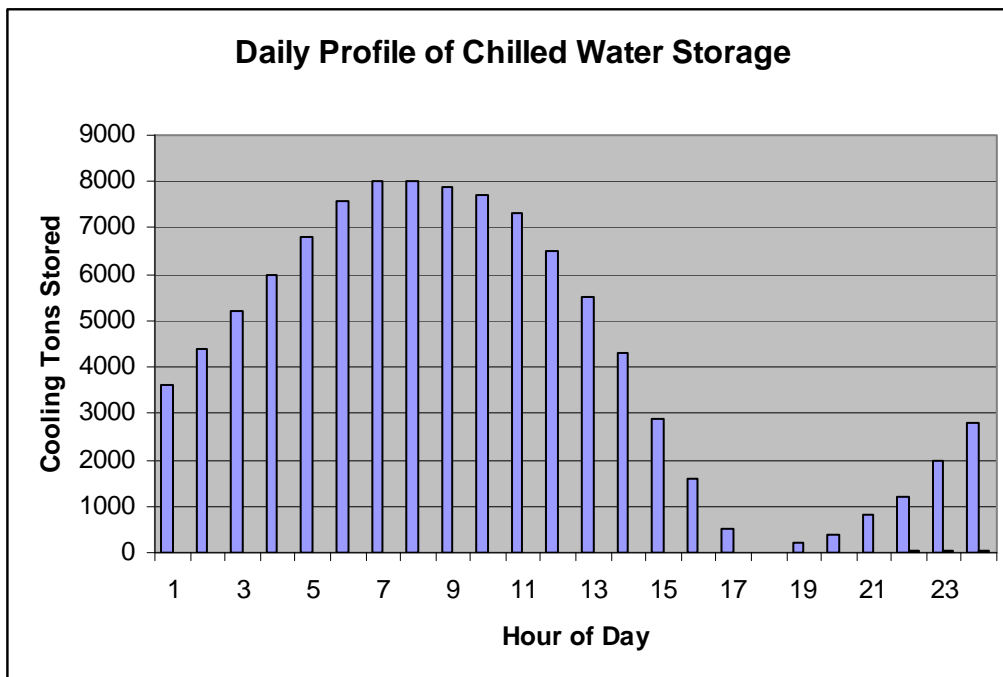


Figure 8. Daily profile of chilled water storage.

An absorber chiller powered by waste heat from the diesel-powered generator can be used to make the chilled water system even more efficient. It is recommended that the absorber chiller be placed in series with an electric chiller to obtain the desired temperature differential. The absorption machine's efficiency is reduced significantly when generating colder water. So the absorber can receive the return water first and the electrical chiller can complete the cooling of this water. This will provide the highest efficiency for making the chilled water. If a thermal storage system is not used, excessive installation and operating costs will result.

### **Savings**

The thermal storage system will spread the electrical use of the chillers and cooling towers throughout the 24-hr period of the day to taking advantage of the reduced electrical rates during the night. Using the 24-hr cooling load profile shown above, the electrical use is estimated to be 30,700 kWh. This value was determined using an electrical use rate of 0.8 kW/ton cooling produced. The electrical cost of using this electricity with no storage is approximately \$5,400 (€4,400) for a day of peak usage as seen in Table 3. With storage the cost would be approximately \$4,900 (€4,100). The annual cost of these two approaches is estimated to be \$587,700 (€485,398 and \$536,600 (€443,194). These values assume there are 1400 equivalent full load hours (EFLH) cooling in a year and the presented cooling load profile had 12.8 EFLH in its 24-hr period. The resulting electrical cost saving is estimated to be \$51,000 (€42,203)/yr. The following Table illustrates this analysis.

### **Investment**

Based on estimates from Means Cost Estimating, the cost of installing a cooling system with four 750-ton chillers is estimated to be \$2,540,000 (€2,100,000) compared to the cost of \$2,420,000 (€2,000,000) for the three 600-ton chiller system. Included in the latter system is \$750,000 (€620,000) for a 500,000 gal (1,900 m<sup>3</sup>) thermal storage tank.

### **Payback**

Simple payback will be immediate since the thermal storage system has a lower installed cost.

Table 3. Electrical cost to provide cooling on peak use day with and without thermal storage.

Hour of Day	Cooling No Storage	Load Tons With Thermal Storage	Electrical No Storage	Use, kWh With Thermal Storage	Power Cost \$/kWh	Electrical No Storage	Cost With Thermal Storage
1	800	1600	640	1280	\$0.1171	\$75	\$150
2	800	1600	640	1280	\$0.1171	\$75	\$150
3	800	1600	640	1280	\$0.1171	\$75	\$150
4	800	1600	640	1280	\$0.1171	\$75	\$150
5	800	1600	640	1280	\$0.1171	\$75	\$150
6	800	1600	640	1280	\$0.1171	\$75	\$150
7	1200	1600	960	1280	\$0.1476	\$142	\$189
8	1600	1600	1280	1280	\$0.1962	\$251	\$251
9	1700	1600	1360	1280	\$0.1962	\$267	\$251
10	1800	1600	1440	1280	\$0.1962	\$283	\$251
11	2000	1600	1600	1280	\$0.1962	\$314	\$251
12	2400	1600	1920	1280	\$0.1962	\$377	\$251
13	2600	1600	2080	1280	\$0.1962	\$408	\$251
14	2800	1600	2240	1280	\$0.1962	\$439	\$251
15	3000	1600	2400	1280	\$0.1962	\$471	\$251
16	2900	1600	2320	1280	\$0.1962	\$455	\$251
17	2700	1600	2160	1280	\$0.1962	\$424	\$251
18	2100	1600	1680	1280	\$0.1962	\$330	\$251
19	1400	1600	1120	1280	\$0.1476	\$165	\$189
20	1400	1600	1120	1280	\$0.1476	\$165	\$189
21	1200	1600	960	1280	\$0.1476	\$142	\$189
22	1200	1600	960	1280	\$0.1476	\$142	\$189
23	800	1600	640	1280	\$0.1171	\$75	\$150
24	800	1600	640	1280	\$0.1171	\$75	\$150
<b>Totals</b>	<b>38400</b>	<b>38400</b>	<b>30720</b>	<b>30720</b>		<b>\$5,373</b>	<b>\$4,906</b>

## CEP #2 Future district heating system as a hot water system

### Existing conditions and problems

The central heating distribution system at the Caserma Ederle supplies at least 90 percent of the buildings on the Base with heat for space and domestic water heating. The central heating plant in Bldg 206 generates heat with four steam boilers (Figures 9 and 10).



Figure 9. Central Energy Plant Bldg 206.



Figure 10. Steam Boilers in Bldg 206.

The steam boilers have the following capacities:

- one boiler      6,000,000 kcal/h (app. 7.000 kW<sub>th</sub>)
- three boilers    3,000,000 kcal/h (app. 3.500 kW<sub>th</sub>).

The boilers are at least more than 30 yrs old and they produce steam at 8 bar pressure, which is reduced to 3 bar for distribution in the steam pipelines.

Under normal circumstances, at peak load time one large and one small boiler is running. Therefore the peak load should be less than 10,500 kW<sub>th</sub>.

The heating distribution system is divided in two circuits: one serving the north part with steam, the other serving the south part with hot water. Figure 11 shows the steam net at the north circuit.

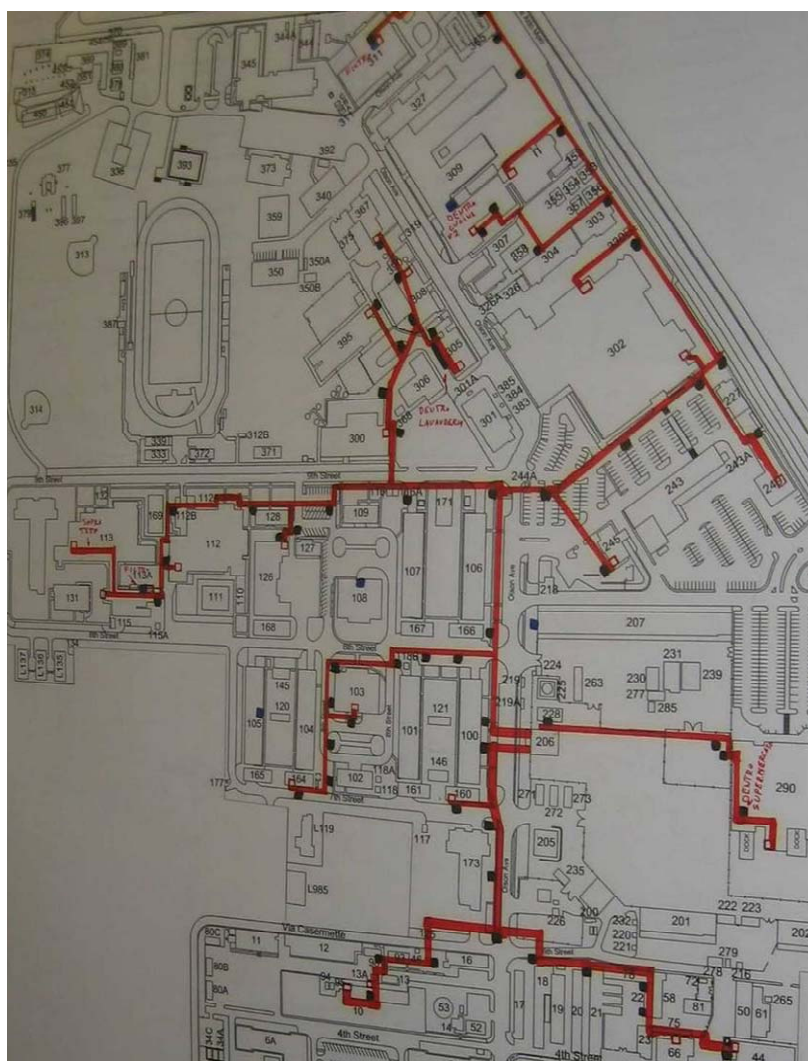


Figure 11. Steam Network at Caserma Ederle.

The steam net consists of a steam and a condensate pipe lying in trenches. As seen in Figure 11, three steam circuits exist:

- north circuit serving the north part of the Base
- south circuit serving Bldgs 10B, 23, 44 and 66
- east circuit serving Bldg 290 (New Commissary building).

The north circuit was recently renovated. Up to the New Recreation Center new steam and condensate Line have been built with a constant size, nominal diameter 200 steam pipe and nominal diameter 80 for the condensate line. The new lines were laid in the old trenches (Figure 12). The steam line was made of black steel, the condensate of stainless steel.

The new steam lines end in new prefabricated heat exchanging stations (Figure 13). Those stations produce hot water as a secondary heat transport medium. Most of the station have been built outside near the new steam distribution lines.



Figure 12. New steam and condensate lines.



Figure 13. New Heat exchanger stations.

The heat exchanger stations consist of a steam-to-hot water heat exchanger, with two groups of circulating pumps for space heating and domestic hot water. The secondary system is a 3-pipe system.

The hot water net in the south part of the Base consists of three pipes: one supply line for space heating, one supply line for domestic water heating and one common return line.

The maximum supply temperature is 80 °C during cold periods; in summer the temperature is reduced to approximately 75 °C.

The space heating in the buildings is directly fed by the district heating system using secondary circulating pumps. The domestic water heating was made by using the supply hot water lines as a primary system for the hot water generators.

#### **New central plant concept**

The existing Central Energy Plant is going to be renovated by an ESPC-Project by Siemens. They will install four new steam boilers and a new co-generation plant.

The new equipment will consist of the following plants:

- three boilers each with a capacity of 8 metric tons/hr steam
- one boiler with a capacity of 4 metric tons/hr steam
- two cogeneration units based on a diesel engine.

The electrical power generation of each unit is approx. 1,500 kW. The heat recovery system is composed by three parts:

- 690 kW<sub>th</sub> – heat recovery from the flue gas producing steam at 4 bar pressure
- 614 kW<sub>th</sub> – heat recovery from the engine cooling producing 85 °C hot water.

The 4-bar steam will be used as primary medium to feed absorption chillers for the new district cooling system in the south part of the Base.

The overall new heat production capacity will be approx. 22,700 kW<sub>th</sub>.

#### **New building structure**

In the near future (probably beginning in 2015), most of the existing buildings will be removed and new buildings will be constructed. Figure 14 shows the new building situation in the future.

At this time a Military Construction (MILCON) construction program indicates seven phases to guarantee the continuous operation of the Base during all work.

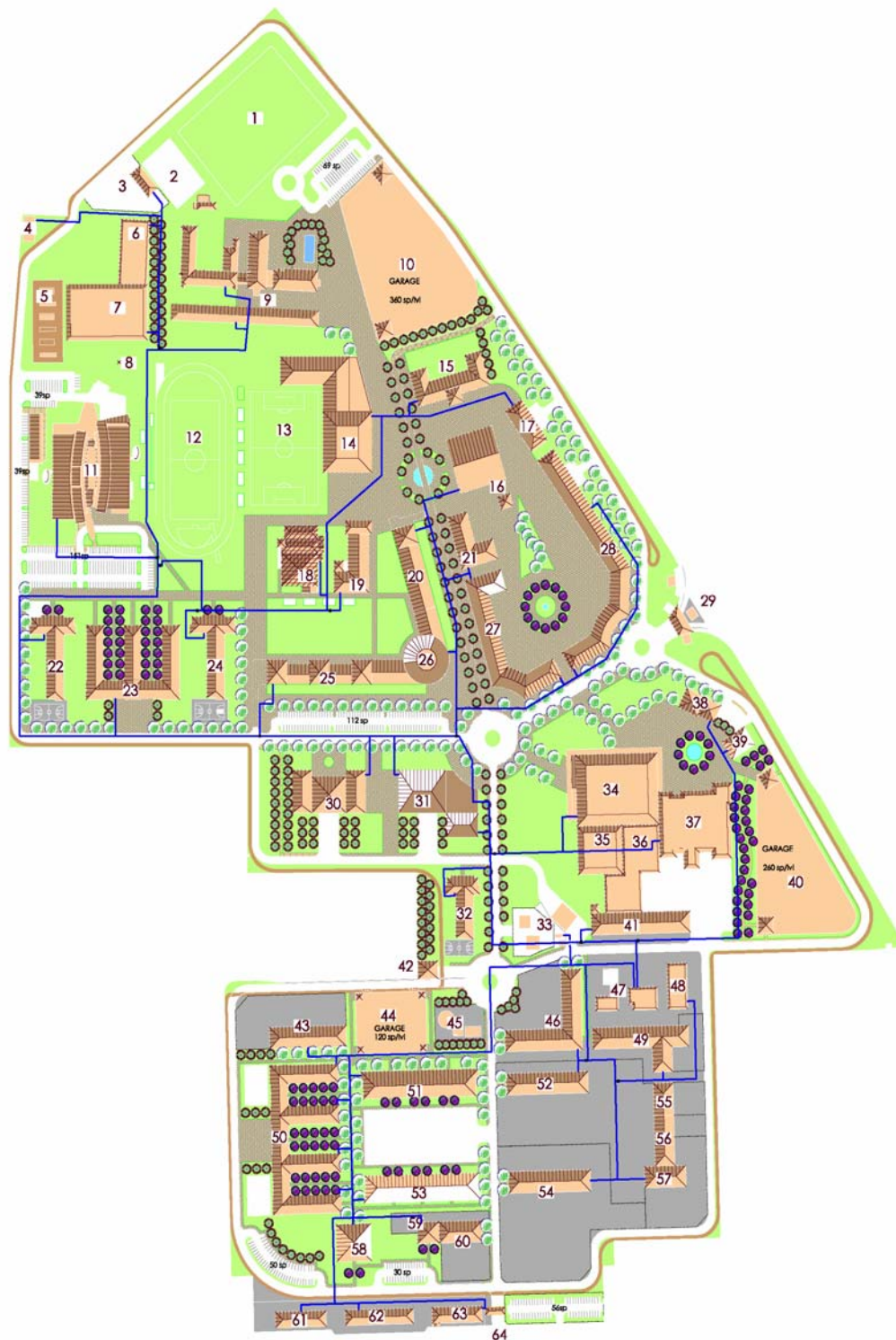


Figure 14. Future building situation.

## Future heating demand

The data in Tables 4 and 5 summarize the future heating demand of each building.

Table 4. Future heating demand north side.

TOTAL HEATING DEMAND - CAMP EDERLE											
BLDG N°	BLDG NAME	PHASE	AREA (m <sup>2</sup> )	FLOOR N.	Space Heating			D. H. W. Heating			Other
					HW Kw	HW l/s	Steam kW	DHW Kw	DHW l/s	Steam kW	
1	MULTI-PURPOSE ATHLETIC FIELD	7	N/A	N/A							
2	TENNIS COURTS	6	N/A	N/A							
3	MAINTENANCE BUILDING	6	150	1			10,5				
4	NBC CHAMBER / JUMP TOWER	6	80	1			6,0				
5	PLF PIT / AIRCRAFT MOCK-UP	6	139	N/A							
6	MULTI-PURPOSE INDOOR RANGE (MIR) / COMBAT IN CITY FACILITY (SHOOTHOUSE)	6	892	1 or 2			62,5				
7	BATTLE COMMAND TRAINING CENTER (BCTC)	6	6.039	2			725,0				
8	HEAT INDEX PAVILION	6	N/A	N/A							
9	EDERLE INN LODGE EXPANSION	1	12.276	3			1048,0			300,0	
10	PARKING STRUCTURE	5	40.563	3							
11	ENHANCED HEALT SERVICE CENTER	1	12.807	2			1850,0			252,0	
12	TRACK / ATHLETIC FIELD	(EXIST.)	N/A	N/A							
13	MULTI-PURPOSE ATHLETIC FIELD	3	N/A	N/A							
14	PHYSICAL FITNESS CENTER	3	5.963	1 or 2			715,0				
15	CHILD DEVELOPMENT CENTER (CDC)	3	3.646	1			365,0				
16	CHAPEL / CAMPANILE	4	2.226	1			200,0				
17	TRAVEL AND RECREATION	3	2.821	2			255,0				
18	SOLDIER AND FAMILY ENTERTAINMENT CENTER	1	2.787	1			620,0			280,0	
19	COMMUNITY ACTIVITY CENTER (CAC) / FESTIVAL PAVILION	5	5.614	3			675,0				
20	COMMAND SUPPORT	4	3.332	2			300,0				
21	FAMILY READINESS	4	1.700	2			204,0				
22	BARRACKS, EXISTING	(EXIST.)	6.675	4			500,0			230,0	
23	BARRACKS, PROPOSED	3	14.260	4			1140,0				
24	BARRACKS, PROPOSED	4	5.750	4			460,0				
25	COMMAND SUPPORT	4	3.794	2			340,0				
26	SETAF HEADQUARTERS	4	11.673	4			1050,0				
27	CENTRAL PROCESSING FACILITY / FINANCE / LEGAL	4	4.607	2			415,0				
28	LIBRARY / ARMY EDUCATION FACILITY / COMMUNICATION CENTER	4	13.522	3			1620,0				
29	MAIN GATE	4	TBD	N/A							

BLDG N°	BLDG NAME	PHASE	AREA (m <sup>2</sup> )	FLOOR N.	Space Heating			D. H. W. Heating			Other
					HW Kw	HW l/s	Steam kW	DHW Kw	DHW l/s	Steam kW	
30	DFAC	2	2.811	1			200,0				
31	ITALIAN MENSA	2	1.161	1			81,5				
32	BARRACKS, EXISTING	(EXIST.)	4.490	4			361,0			149,0	
34	CONSOLIDATED OPEN DINING	3	14.357	3			1005,0				
35	POST EXCHANGE	3	5.983	3			718,0				
36	PX WAREHOUSE	3	5.574	2			400,0				
37	COMMISSARY	(EXIST.)	5.071	1			261,0			78,5	
38	SHOPPETTE	4	730	1			87,6				
39	APO / CMR	4	532	1			50,0				
40	PARKING STRUCTURE	3	19.432	2							
41	AAFES AUTO AREA / MWR AUTO AREA / POV INSPECTION / POL OFFICE	3	2.105	2			150,0				
42	GATE 4 ACP	2	TBD	N/A							
Total North Side							15875,1			1289,5	

Table 5. Future heating demand south side.

BLDG N°	BLDG NAME	PHASE	AREA (m <sup>2</sup> )	FLOOR N.	Space Heating			D. H. W. Heating			Other
					HW Kw	HW l/s	Steam kW	DHW Kw	DHW l/s	Steam kW	Steam kW
33	POL	(EXIST.)	370	1	5,8	0,042					
43	DIRECTORATE OF EMERGENCY SERVICES (DES)	2	3.882	3	348,0	2,519					
44	PARKING STRUCTURE	7	6.020	2							
45	WATER STORAGE TANK / PUMP	2	N/A	N/A							
46	DOL / DPW	2	4.864	2	422,5	3,058					
47	HEATING PLANT / FUEL	2	TBD	1							
48	ECO / DRMO / HAZMAT	4	844	1							
49	DOL / DPW	4	7.416	3	668,0	4,835					
50	BARRACKS, PROPOSED	2	18.790	4	1505,0	10,893					
51	INF CO HQ	2	7.846	3	550,0	3,981					
52	INF BN MAINTENANCE	2	1.839	1	115,0	0,832					
53	INF CO HQ	2	7.846	3	550,0	3,981					
54	INF BN MAINTENANCE	2	1.839	1	115,0	0,832					
55	509th SIGNAL NETWORK HUB	2	606	4	54,6	0,394					
56	AFN MOTORPOOL	2	934	1	66,6	0,474					
57	14th TRANSPORTATION	2	2.796	4	198,0	1,419					
58	INF BN HQ	2	2.884	3	188,0	1,361					
59	HOST NATION MOTORPOOL	2									
60	AIR FORCE MAINTENANCE	2	889	1	81,0	0,442					
61	HOST NATION	(EXIST.)	2.829	3	100,0	0,724		3,2	0,045		
62	CONTROLLED PUBLIC ACCESS ZONE	(EXIST.)	1.471	2	172,3	1,247					
63	CONTROLLED PUBLIC ACCESS ZONE	(EXIST.)	1.960	2	100,5	0,727					
64	GATE 2 ACP	(EXIST.)	TBD	N/A							
<b>Total South Side</b>					<b>5217,1</b>	<b>37,760</b>		<b>3,2</b>	<b>0,045</b>		
<b>Total Base</b>					<b>5217,1</b>	<b>37,760</b>	<b>15875,1</b>	<b>3,2</b>	<b>0,045</b>	<b>1289,5</b>	
<b>Total Base Heating Demand (kW)</b>											

Extrapolating from that data in Tables 4 and 5, the installation's future heating demand will be:

The total base heating demand	=	22,385 kWth.
For the north part the heating demand	=	17,165 kWth
The annual heat consumption is about 1000 h/yr x 22,385 kWth	=	22,385 MWh/yr
Only for the north circuit	=	17,165 MWh/yr.

### Future distribution concept

The designers of the "Long Range Utility Distribution System," the OK Design Group S.R.L., are planning a district heating configuration that will consist of two separate circuits starting from the new central heating plant in Bldg 47.

The north side circuit will be a steam and condensate net with steam-to-water heat exchangers in each building requiring space and domestic water heating. Buildings requiring steam directly (i.e., Dining Facilities and the Commissary), will have steam and condensate circuits within the buildings, directly branched to the steam distribution net.

The south side circuit will be a hot water net consisting of four pipes. Two pipes (supply and return) will serve the domestic water heating requirement. The two other pipes will be a dual temperature water circuit (chilled/hot water supply and return) serving in winter the space heating requirement and in summer the cooling requirement.

### **Solutions**

The idea is to install a complete hot water district heating system for the whole base as a two-pipe system with a supply and return line. This system will provide the space heating and domestic hot water requirements. In addition a separate chilled water distribution net is recommended. The new hot water system will consist of direct-buried steel pipes insulated by a polyurethane foam with a high density polyethylene covering. This pipe will come with a leak detection system so that future leaks can be easily located. It will be constructed without any pit holes or compensators. If shut-off valves were needed, it is possible to use valves for subsurface installation. This pipe system is the cheapest system available in the market. In Germany this system has a market share in new installations of over 90 percent.

This system will be controlled to provide the hottest water with 100 °C only during the coldest winter days. During other times the hot water temperature can be lowered and still meet the heating needs. During the summer, when heat is required by only the domestic hot water heaters, a hot water temperature of 70 °C can be supplied. This will reduce the heat losses through the pipe distribution system, help avoid the energy waste of overheating these buildings, and lengthen the life of the distribution pipes due to less stress of expansion and contraction.

A steam system cannot use this cheap pipe system and (and would cause higher maintenance costs) because a steam system has higher temperatures are heat losses than a hot water system. On the installation, only a small amount of steam is directly required (e.g., at the dining facilities). Therefore, it is recommended that only buildings with requirements for steam have small steam boilers installed. For the future heat requirements, new hot water net pipe dimensions were calculated for a supply temperature of 100 °C and a return temperature of 50 °C. Figure 15 shows the resulting pipe diameters.

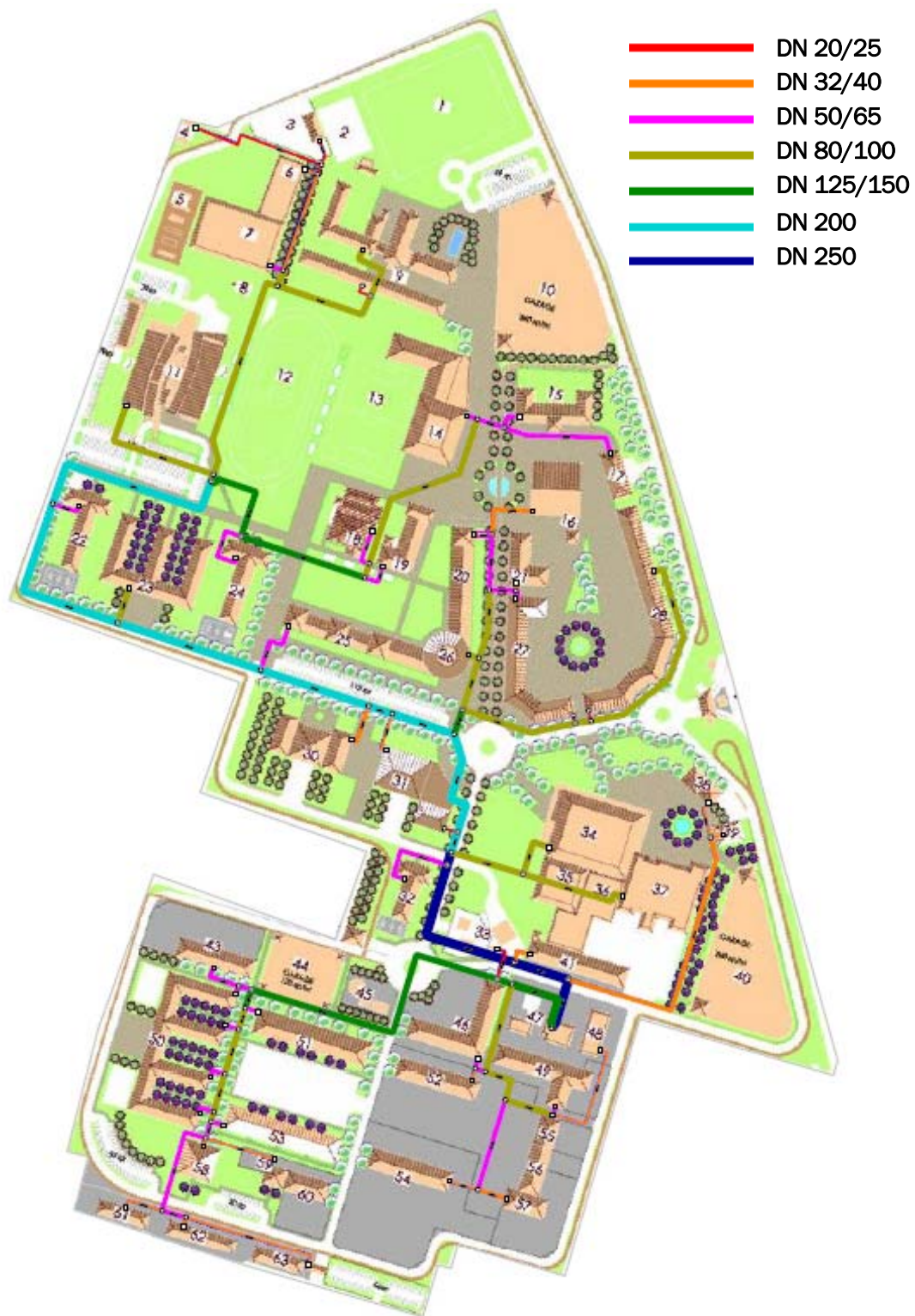


Figure 15. Future hot water net – pipe diameters.

Table 6 lists the first cost requirements for the new hot water net. The specific costs are a result of recently built pipelines and 25 yrs of experience in planning such pre-insulated pipes. The price base is 2008.

Table 6. First cost requirements new hot water net.

Nom. Dia (DN)	Length (m)	Spec. Cost (TSD. €)	First Cost (TSD. €K)	First Cost (K\$)
20	243	280	68	95
25	242	290	70	98
32	460	310	143	200
40	537	335	180	252
50	713	360	257	359
65	450	410	185	258
80	525	460	242	338
100	1529	525	803	1124
125	688	575	395	553
150	89	625	55	77
200	1008	750	756	1068
250	324	1000	324	454
<b>Total</b>	<b>6808</b>	<b>5920</b>	<b>3478</b>	<b>4876</b>

Thus the total pipe length (trace) is 6.8 km and the first cost requirements for the installation of a new hot water net is \$4,870 K. The north part of the net, which is planned to stay on steam, has a total pipe length of 4.9 km and first cost requirements of \$3,750K (Table 7). The south circuit will cost \$1,120K.

Table 7. First cost requirements new hot water net, north part.

Nom. Dia (DN)	Length (m)	Spec. Cost (TSD. €)	First Cost (TSD. €K)	First Cost (K\$)
20	201	280	56	79
25	30	290	9	12
32	204	310	63	89
40	482	335	162	226
50	350	360	126	176
65	352	410	144	202
80	403	460	185	260
100	1304	525	684	958
125	295	575	169	237
150	0	625	0	0
200	1008	750	756	1058
250	324	1000	324	454
<b>Total</b>	<b>4953</b>		<b>2678</b>	<b>3751</b>

In the buildings, the connection to the district heating net requires heat exchanger stations. Those compact prefabricated stations cost about €40/kWth. For all building stations this requires an investment of \$1,250 K (€895 TSD.), only for the north part the first costs are \$961K (687 TSD.).

### **Savings**

Many difficult dependencies must be considered to calculate the savings of a complete hot water system in comparison with distribution concept of the OK group, north part steam, and south part hot water. This first phase study discusses only the main effects. A detailed study will be necessary to analyze all influences. The following sections outline the assumptions that can be used to perform a rough estimation of the potential of this measure.

## **Reducing investment costs.**

### **Distribution net**

The investment costs of new pipelines lying in concrete trenches is 20 percent higher than for pre-insulated direct-buried pipes. The investments required for steam system pipes will cost 30 percent more than those for hot water pipes because the complicated (steam) condensate system requires more pit holes.

Thus, for the north part, a new steam/condensate system costs about:

$$1.3 \times \$3,750\text{K} = \$4,875\text{K}.$$

The savings for the north part are:

$$(\$4,875 - \$3,750)\text{K} = \$1,125\text{K}.$$

For the south circuit, investment costs are estimated to be:

$$1.2 \times \$1,120\text{K} = \$1,344\text{K}.$$

The savings for the south part are:

$$(\$1,344 - \$1,120)\text{K} = \$224\text{K}.$$

The total savings in the distribution net are \$1,349K, or with an annuity factor of 7.5 percent/yr (40 yrs, interest 7 percent): \$102K/yr.

*Building stations*

Building stations in the steam net are 25 percent more expensive than hot water stations. Thus the investment savings for the north circuit is:  $(25\% \times \$961\text{K}) \$240\text{K}$ , or with an annuity factor of 9.44%/yr (20 yrs, interest 7%), a yearly saving of \$23K/yr.

*Reducing heat losses*

The heat losses in a new hot water system running all year round is about 8 percent of the produced amount of district heating. Because of higher temperatures, the heat losses in a steam distribution net are about 15 percent of the yearly heat production.

For the north part, the savings of heat losses are:

$$(15-8)\% \times 17,200 \text{ MWh/a} = 1,200 \text{ MWh/yr}$$

The heat price of a gas fired boiler today is \$0.0506/kWh. The price of the cogeneration heat must be cheaper, estimated at \$0.04/kWh. It is also estimated that cogeneration will make up 60 percent of the heat production.

Thus the mixed heat price is:

$$0.6 \times 0.04 + 0.4 \times \$0.0506/\text{kWh} = 0.0442 \text{ $/kWh.}$$

and therefore, the cost savings are:

$$1,200 \text{ MWh/yr} \times \$44.2/\text{MWh} = \$53\text{K/yr}$$

*Reducing maintenance costs*

The maintenance of a hot water net is much cheaper than a steam net. Typical maintenance costs for a hot water net is about \$4,000 / (km x yr). For a steam net, it is at least doubled.

Therefore, the annual savings for the north circuit are:

$$\$4,000/\text{km yr} \times 4.9\text{km} = \$20\text{K/yr}$$

*Electricity for circulation pumps*

Additional electrical energy for pumping the hot water is necessary for the north circuit. Electrical demand is estimated at:

$$25 \text{ kW} \times 6000 \text{ h/yr} = 150 \text{ MWh/yr}$$

With a blended electrical rate of \$0.15 /kWh, additional costs are \$23K/yr.

To summarize, the total annual savings are:

Reducing investment costs distribution net	\$102K/yr
Reducing investment costs building stations	\$23K/yr
Reducing heat losses	\$53K/yr
Reducing maintenance costs	\$20K/yr
Increasing electricity for pumps	-\$23K/yr
Total annual savings	<hr/> \$175K/yr

**Payback**

The payback period for installing a complete hot water distribution system compared to a partial steam net is 0 yrs, because the resulting first cost requirements and the annual costs are lower than the current costs.

Table 8. Summary of central energy plant ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Electrical Use, Elec Demand, Thermal, and (Maint (\$/yr))	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
CEP #1	Thermal storage system	0	0	\$51,000	0	\$—	\$—	\$51,000	-\$120,000	-2.4
CEP #2	Future district heating system as a hot water system	-150,000	0	-\$22,566	4,096	\$53,000	\$20,000	\$50,434	-\$1,589,000	-31.5
<b>Totals</b>		<b>-150,000</b>	<b>0</b>	<b>28,434</b>	<b>4,096</b>	<b>53,000</b>	<b>20,000</b>	<b>101,434</b>	<b>-1,709,000</b>	<b>-16.8</b>

## 5 Controls (CON)

Heating, Ventilating, and Air-Conditioning (HVAC) systems were found to have significant savings potential. Because much of the savings could be obtained by performing various changes to the controls, those projects were separated from other HVAC projects involving more substantial (costly) changes.

### CON #1. Fix/replace HVAC controls

#### Existing conditions/problems

This proposal is part of the general need to re-commission building controls and HVAC equipment all over Ederle Caserma. The conditions at Bldg 311 are unique and are described to show the urgent need to get these controls fixed.

Bldg 311 is the old Club, now converted to Administrative space. It has four roof top air handling units (RTUs, cf. Figure 16). These are placed on the external roof, which is very hot since it is partly black. (See also the write-up on Cool Roofs BE#1 [p 9]). Every individual RTU is controlled by a control unit located in close proximity to the RTU. The setpoints are not uniform and the RTUs run 24/7. The hours of operation inside the building normally are M-F, 8 a.m. to 5 p.m. The total number of opening hours then are 45 hrs/wk and the RTUs run 168 hrs/wk (cooling or heating unnecessarily during 123 hrs/wk). RTUs could be started 1 hr before opening time and shut down half an hour *before* closing time.

The main problems, though, are related to controls of the units. The actuator for the control valve at the heating coil of the largest RTUs is stuck at 100 percent open, thus providing heat to the heating coil all the time. During the visit, the supply air temperature from this unit into the building was 45 °C (113 °F) and the space temperature was close to 29 °C (85 °F). It was close to unbearable in the admin space and the people working in there complained severely about the heat.



Figure 16. Roof top air handling units at Bldg 311.

The other three RTUs are smaller. They had discharge air temperatures of 32 °C, 38 °C and 37 °C respectively (90, 100 and 99 °F). The setpoints were 24.5 °C, 34 °C, and 28 °C respectively for these RTUs (76, 93 and 82 °F). This is of course far too hot for any space at Ederle Caserma, may it be winter or summer.

It was found difficult to change the setpoints to a more reasonable level (around 21 °C); in fact, it could not be done with the existing controls.

At the entrance to the roof, via the ladder, there is also an uninsulated heat exchanger. The external temperature was 55 °C. Heat losses are substantial and highly dependent on the outdoor air temperature. The hot water temperature is also higher as outdoor temperature gets lower, thus increasing the temperature difference that drives the heat losses (Figure 17).

The space in Bldg 311 was also slightly under-pressurized, indicating that the air balance might be corrupt, caused by either failing dampers, clogged filters, or other problems.



Figure 17. Uninsulated heat exchanger at Bldg 311.

### **Solution**

The best solution would be to connect Bldg 311 to the Siemens Energy Management Control System (EMCS), but *only* if the building will remain at base long enough to make it worthwhile. The EMCS would enable better control and supervision of control systems operation, time scheduling, set-point controls etc. Otherwise this study proposes the replacement of existing controls, replacement of the non-functioning actuator, installation of programmable timers with weekly schedules, establishment of fixed and uniform setpoints, and the insulation of the heat exchanger according to standards for the Vicenza climate conditions.

## Savings

The savings by reducing the operating hours, to match building occupancy, will be included in the ECM CON #2. The calculations below only determine the savings by replacing the controls and fixing the problems related to space temperature control. However, when calculating the energy wasted with the present mode of operation, with over-heating, the operating hours of 168 hrs/wk will be used.

The air flow data for the RTUs were not available, but were estimated to be 12,000, 6,000, 4,200 and 4,200 cfm, respectively, based on the physical size of the units. Making a rough calculation, running all the RTUs at 30 percent Outside Air flow (assumed) and overheating the space by 8 °C during 168 hrs/wk all year long, gives the following energy use for heating:

RTU1 total min. outdoor air (OA):	3,600 cfm = 1.7 m <sup>3</sup> /s
RTU2 total min. OA:	1,800 cfm = 0.85 m <sup>3</sup> /s
RTU3 and 4 total min. OA:	2,500 cfm = 1.2 m <sup>3</sup> /s (both RTUs together)
Total OA:	<hr/> 3.7 m <sup>3</sup> /s

## Heating

$$3.7 \text{ m}^3/\text{s} \times 1.2 \text{ kJ/kg } ^\circ\text{C} \times 8 ^\circ\text{C} \times 8760 \text{ hrs/yr} = 310 \text{ MWh (1,060 MMBtu/yr)}$$

A cost of €14.8/MMBtu for natural gas, with 85 percent boiler efficiency results in:

$$1,060 \text{ MMBtu} \times \$14.8/\text{MMBtu} / 0.85 = \$18.5\text{K/yr}$$

Savings from insulating the heat exchanger are estimated to be around €500/yr.

By fixing the RTU controls and the actuator, and by insulating the heat exchanger, total savings then sum up to \$19K/yr.

Note that it is not known that the RTUs run at min. Outdoor air (OA); they could all very well be running at 100 percent OA, due to the lack of controls. If that is the case, of course the savings will be much greater.

It is not easily determined what results in terms of increased productivity that can be achieved by fixing the problems in Bldg 311, but these gains may well be *higher than the energy savings*.

### **Investment**

Based on past experience, required investments are estimated to be €3,000 for the large RTU, €2,000 each for the smaller ones, and €200 to insulate the heat exchanger or a total of less than €10,000.

### **Payback**

Simple payback will occur within 0.6 yr.

## **CON #2. Reduce HVAC run time/schedule AHUs to match building occupancy**

### **Existing conditions/problems**

Many AHUs at Ederle Caserma are operating 24/7 or close to that, due to the lack of time schedules (which the few units that are connected to either of the three EMCS systems have) or because the time clocks for the AHUs are set to operate 24/7. This is not necessary since most buildings are not normally used more than 8–12 hrs/day, 5 days/wk. Some secure areas may run for longer periods, but not continuously. Running an air handling unit (AHU) for more hours than necessary means that energy is wasted for heating, for cooling and for running fan motors. Since most AHUs do not have VFDs, they also run at 100 percent capacity all the time.

Buildings that were noticed to have far longer operating hours than necessary could be easily identified by physical inspection in buildings with AHUs where EMCS is not installed. In buildings with time clocks for AHUs, the clocks either do not operate anymore because they were not maintained or disposed of when they stopped functioning, or the clocks are always *On*.

### **Solution**

In buildings where EMCS is not yet installed, install programmable timers with weekly schedules or start using existing time clocks. Make sure that the timers are checked and maintained regularly. Program them for oper-

ating hours matching building occupancy, different in every building. Where AHUs are connected to EMCS, ensure that the time schedule module in the EMCS software is used to its full capacity.

### **Savings**

Reducing the running hours for an AHU with normal functions, i.e., everything works as it is intended to (after fixing malfunctioning equipment), from 168 hrs/wk (24/7) to 60 hrs/wk (12/5), with 20,000 cfms, 30 percent outdoor air in both winter and summer for economizing reasons (which is not fully used at Ederle, see ECM HVAC-3), and with a 10 hp supply air fan and 8 hp return air fan, can be calculated.

### *Assumptions*

Vicenza climate includes the following heating/cooling degree days:

4,284 heating degree days (°F) = 2,380 degree days (°C)

1,102 cooling degree days (°F) = 612 degree days (°C)

### *Heating*

At a cost of \$14.82/MMBTu and 85 percent total boiler plus distribution efficiency:

30% OA = 6,000 cfm = 2.8 m<sup>3</sup>/s. Heating : 2.8 m<sup>3</sup>/s x 1.2 kJ/kg, °C x 2,380 degree days x 24 hrs/day = 192 MWh (655 MMBtu/yr)

### *Savings*

655MMBTu/yr x 14.82/0.85 = \$11,422/yr (€13,830)

### *Cooling*

Using a coefficient of performance (COP) of 3.0:

Savings = 2.8 m<sup>3</sup>/s x 1.2 kJ/kg, °C x 612 degree days x 24 hrs /3.0  
= 16,451 kWh

= \$2,475 (E 2,054)

Motor savings: (10 + 8 hp) x 0.746 kW/hp x (168 – 60 hrs) x 52 wks  
= 75 MWh/yr

= \$11.3K (€9.3 k/yr)

Total savings then equal \$25.2K (€20.8K/yr). If this were done on 10 similar units, then the savings amount to \$252K (€208K). In the actual buildings, the maintenance costs can also be significantly reduced due to fewer operational hours/yr. (Filters stay clean longer, belts last longer, etc.) From the findings at Ederle, regarding AHUs running 24/7 for no real reason, it is safe to say that this ECM can be extrapolated to at least the equivalent of 10 units at 20,000 cfm each, thus generating total savings of almost €260 k/yr.

### Investment

The investments are moderate or very low:

- In buildings not connected to EMCS: New programmable timers, an average of €2,000/20,000 cfm. If several are done under the same project the average cost would be much less.
- In buildings attached to EMCS: No additional investment is needed.
- For 10 Ederle Caserma AHUs: €1,500/AHU (average ) or €15K (total).

### Payback

Simple payback will occur within 0.1 yr.

## CON #3. Consolidate HVAC control systems

### Existing conditions/problems

Ederle Caserma has three different Energy Management and Control Systems (EMCS), with the main operator terminals located in Bldg 20, DPW. The EMCS' are:

- **Siemens Insight** for Bldgs 10, 28, 29, 82, 103, 301, 302 and the Boiler Plant in Longare
- **Honeywell** for Bldgs 290, 327, 395, 398 and the Library and the Post Office, both in Bldg 302 (Post Exchange [PX])
- **Sauter** for the new barrack Bldgs 170 and 173.

In total, these three systems only cover 14 different buildings. In addition to this, there is also a separate system (Energy Brain) for meter readings.

The problem with three different systems is to keep updated on the functions and special features of every specific system, to decide on which

software updates to purchase and when. The system maintenance and updating costs normally also triple with three systems.

### **Solution**

This study recommends a Phase II study at this installation. CERL has performed several EMCS master plan studies and it is recommended that one be performed at the Vicenza installations. This study should address the following issues:

1. *Consolidation of the HVAC control systems.* The natural solution is to use the Siemens Insight as base due to the Siemens Energy Savings Performance Contract ESPC. Siemens Insight has the advantage of being based on Citect software, which enables multiple choices regarding hardware and components.
2. *Add more buildings and systems to the EMCS.*
3. *Reduce the dependency on local timers, local controls and people by installing new DDC controls, automated time controls, and startup sequences etc.* At this stage, after having visited Ederle Caserma and becoming familiar with the Master Plan and its upcoming demolitions and new constructions, this study recommends that (at least) Bldgs 1, 2, 3, 108, 112, 309, 311 and 345 be modernized with new DDC controls and connected to the Siemens EMCS.

### **Savings**

Savings are not easily calculated at this stage, but it is anticipated that they will be substantial.

### **Investment**

An incremental investment to a system that already exists in its essential parts will not be expensive and will give a good return on investment.

### **Payback**

A very rough estimate indicates that simple payback will occur, on average, between 2 to 3 yrs for this kind of incremental investment. A Phase II study will be necessary to more accurately determine payback time. Some investments will have a very short payback period.

Table 9. Summary of controls ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
CON #1	Fix/replace HVAC controls	0	0	\$—	1,247	\$19,089	\$—	\$19,089	\$12,108	0.6
CON #2	Reduce HVAC run time/schedule AHUs to match building occupancy	914,510	0	\$137,579	7,706	\$114,217	\$—	\$251,795	\$18,000	0.1
CON #3	Consolidate HVAC control systems	0	0	\$—	0	\$—	\$—	\$—	\$—	—
<b>Totals</b>		<b>914,510</b>	<b>0</b>	<b>137,579</b>	<b>8,953</b>	<b>133,306</b>	<b>0</b>	<b>270,885</b>	<b>30,108</b>	<b>0.1</b>

## 6 Dining Facilities

Dining facilities are very energy intensive and hence often present significant energy savings opportunities. Any replacement equipment should be ENERGY STAR® rated; however the significant initial cost rarely warrants replacement for energy savings reasons. The following ECMs are relatively inexpensive projects that can be done at any time.

### DIN #1. Modify kitchen hoods with end skirts, Bldg 745

#### Existing conditions

The hoods used in the kitchen of the Dining Facility (Figure 18) would be a standard canopy type that most likely will be placed against a wall. Assume there are three hoods that are an average of 12 ft (3.7 m) long and 4 ft (1.2 m) wide. For extra heavy use, the exhaust rate of such a canopy hood against a wall is 550 CFM per linear foot of hood, according to the 2003 Mechanical Code:  $Q = 550 \text{ CFM/ft} \times 12 \text{ ft} = 6,600 \text{ CFM}$



Figure 18. Typical kitchen hood with no extensions down or skirts at ends.

The hoods are located 3 1/2 ft (1.1 m) above the cooking surface. Given the hood size the three hood exhaust systems would each remove 6,600 CFM (3,100 L/s) for a total exhaust of 19,800 CFM (9,300 L/s) of air. These hoods would operate approximately 13 hrs/day, 7 days/wk. The kitchen hood ventilation system is a large energy user. First there is an electrical use of operating the exhaust fan motors. There is also a supply air system that must operate to deliver make-up air for the hood exhaust. There is an electrical use to power these fans and to operate the chillers that cool this air in the summer. In the winter, heat is required to temper the air to avoid cold spots in the kitchen.

### **Solution**

The exhaust air from the kitchen hoods can be made to perform more effectively by adding skirts or wings on the left and right sides of the hood. These skirts would in essence extend the hood sides lower to better encapsulate the kitchen cooking devices that have been placed under the hood. This would allow the hood to better capture the cooking fumes and could slightly reduce the exhaust air flow by this performance improvement. Once the skirts are added, the hood exhaust system air flow would need to be readjusted by testing the hood's performance. Issues such as room air movement can negatively affect hood performance so the new air flow rates would need to take those site conditions into account when making reductions in hood exhaust air flow. If the hood skirts are not added, the kitchen hoods would exhaust a higher air flow, which relates to an excessive amount of energy use.

### **Energy savings**

It is estimated that adding skirts to the kitchen hoods would allow a 10 percent reduction in exhaust air flow while achieving the same current hood capture performance. The estimated total exhaust air fan horsepower required is 22.5 and the supply air system requires 15 horsepower (hp). A reduction of 10 percent air flow has a motor horsepower equal to the cube of that reduction or  $0.9 \times 0.9 \times 0.9 = 73$  percent, which is a saving of 27 hp for the supply and exhaust systems, therefore:

$$\begin{aligned}\text{Fan motor power reduction} &= 37.5 \text{ hp} \times 0.27 \times 0.746 \text{ kW/hp} \times 91 \text{ hrs/wk} \times 52 \text{ wk/yr} \\ &= 7.6 \text{ kW} \times 4732 \text{ hrs/yr} \\ &= 36,000 \text{ kWh/yr.}\end{aligned}$$

The reduced air flow also provides reduced air tempering energy use. The 19,800 CFM (9,300 L/s) requires approximately 40 tons of cooling using 500 CFM for ton, therefore:

$$\text{Extra cooling} = 1.08 \text{ Btu}/(\text{CFM} \times ^\circ\text{F} \times \text{Hr}) \times 19,800 \text{ CFM} \times (92 - 72) ^\circ\text{F} \times 10\% \times 1400$$

$$\text{EFLH/yr} = 60 \text{ million Btu/yr}$$

$$\text{Cooling Energy Used} = 60 \text{ million Btu}/12000 \text{ Btu/ton hr} \times 1 \text{ kWh/ton hr} = 5,000 \text{ kWh/yr}$$

$$\text{Electrical cost savings} = 41,000 \text{ kWh/yr} \times \$0.15044/\text{kWh} = \$6,200/\text{yr} \text{ or } \text{€}5,100/\text{yr}$$

$$\text{Heating savings} = 1.08 \times 19,800 \text{ CFM} \times 10\% \times 4585 \text{ degree days} \times 24 \text{ hr/day}$$

$$= 235 \text{ million Btu/yr} \text{ or } 68.9 \text{ MWh/yr}$$

$$\text{Heating cost savings} = 235 \text{ million Btu/yr} \times \$22.41/\text{million Btu} = \$5,300/\text{yr} \text{ or } \text{€}4,400/\text{yr}$$

$$\text{The total estimated cost savings is } \$11,500/\text{yr} \text{ or } \text{€}9,500/\text{yr}$$

### **Investment**

The estimated cost to provide 4x4-ft long skirts to each side of the three hoods is \$6,000 (€5,000).

### **Payback**

Simple payback will occur in 0.5 yrs

## **DIN #2. Variable flow kitchen hoods**

### **Existing condition**

Kitchen hoods located in Dining Facilities typically operate through the working hours of the kitchen (Figure 19). These hoods continue to exhaust air even though there is no cooking being done. Thus the hoods operate when there is no need, and energy is wasted. For this example the same kitchen hood as in the previous ECM will be used (three hoods 12 ft long and 4 ft wide).

The total air flow exhausted from these hoods after skirts are added is 17,800 CFM ( 8,400 L/s), which operates from 5:00 a.m. to 6:00 p.m. every day of the week. Each hood is powered by a 7.5 horsepower motor for a total of 22.5 horsepower.



Figure 19. Kitchen hood that is good candidate for variable air flow.

### Solution

Sensors can be placed on the exhaust system that will vary the air flow. An optic sensor in the hood will monitor the presence of smoke and cooking vapors. A temperature sensor placed in the duct attached to the hood will note an increase in temperature. The start of cooking activities under the hood will provide a positive indication by either of these sensors and the exhaust air flow will be increased. If the hood monitors are not added, the kitchen hoods would exhaust a higher air flow, which relates to an excessive amount of energy use.

### Savings

The kitchen hood has cooking operations occurring under it for 6 hrs/day. Thus for 7 hrs/day its air flow could be reduced from 5,940 CFM to a flow of approximately 2,970 CFM for each hood. This would provide a reduced horsepower use equal to the cube of  $2,970/5,940$  or approximately 20 percent of an exhaust fan motor of 7.5 hp when motor losses are included. The savings difference of the previous ECM if implemented is 63 percent of the motor electrical use over the 6 hrs/day or 42 hrs/wk. This ECM applies to three hoods having a motor horsepower of 22.5 and a supply motor horsepower of 15, therefore:

$$\begin{aligned}
 \text{Fan motor power reduction} &= 37.5 \text{ hp} \times 0.53 \times 0.746 \text{ kW/hp} \times 42 \text{ hrs/wk} \times 52 \text{ wk/yr} \\
 &= 14.8 \text{ kW} \times 2184 \text{ hrs/yr} \\
 &= 32,000 \text{ kWh/yr.}
 \end{aligned}$$

The reduced air flow also provides reduced air tempering energy use. If the previous ECM is adopted the adjusted air flow would be 17,800 CFM ( 8,400 L/s) requires approximately 35 tons of cooling using 500 CFM for ton, therefore:

$$\begin{aligned}\text{Extra cooling} &= 1.08 \times 17,800 \text{ CFM} \times (92 - 72) ^\circ\text{F} \times 50\% \times 6 \text{ hrs/ } 13 \text{ hrs} \times 1400 \text{ EFLH/yr} \\ &= 124 \text{ million Btu/yr}\end{aligned}$$

$$\begin{aligned}\text{Cooling Energy Used} &= 124 \text{ million Btu/} 12000 \text{ Btu/ton hr} \times 1 \text{ kWh/ton hr} \\ &= 10,000 \text{ kWh/yr}\end{aligned}$$

$$\text{Electrical cost savings} = 42,000 \text{ kWh/yr} \times \$0.15044/\text{kWh} = \$6,300/\text{yr} \text{ or } \text{€}5,200/\text{yr}$$

$$\begin{aligned}\text{Heating savings} &= 1.08 \times 17,800 \text{ CFM} \times 50\% \times 4585 \text{ degree days} \times 24 \text{ hr/day} \\ &\times 6 \text{ hrs/ } 13 \text{ hrs} = 488 \text{ million Btu/yr or } 7,787 \text{ MWh/yr}\end{aligned}$$

$$\begin{aligned}\text{Heating cost savings} &= 488 \text{ million Btu/yr} \times \$22.41/\text{million Btu} \\ &= \$10,900/\text{yr} \text{ or } \text{€}9,000/\text{yr}\end{aligned}$$

The total estimated cost savings is \$17,200/ yr or €14,200/yr.

### **Investment**

The estimated cost to provide temperature and smoke detectors and the controls to adjust fan speed for the exhaust and supply air system is approximately \$11,000 (€9,100). Based on Means, the cost to have variable speed motors for the three 7.5 hp motors and the 15 hp supply fan is \$15,400 (€12,700) for a total cost of \$26,400 (€21,800).

### **Payback**

Simple payback will occur in 1.5 yrs.

Table 10. Summary of dining facility ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
DIN #1	Modify kitchen hoods with end skirts, Bldg 745	41,000	0	\$6,168	235	\$5,266	\$—	\$11,434	\$6,000	0.5
DIN #2	Variable flow kitchen hoods	42,000	0	\$6,318	488	\$10,936	\$—	\$17,255	\$26,400	1.5
<b>Totals</b>		<b>83,000</b>	<b>0</b>	<b>12,487</b>	<b>723</b>	<b>16,202</b>	<b>0</b>	<b>28,689</b>	<b>32,400</b>	<b>1.1</b>

## **7 Heating, Ventilating, and Air-Conditioning (HVAC)**

HVAC systems present significant savings potential at Caserma Ederle. The opportunities range from simple “easy to implement” strategies (such as instituting uniform space temperature setpoints) to fairly complex endeavors (such as re-commissioning and partial replacement of systems).

### **HVAC #1. Shower gray water heat recovery**

#### **Existing conditions**

In the barracks, there are two high water use periods when the soldiers are taking showers. The first is after physical training (PT) about 7:30 a.m. to 8:00 a.m. The other period is in the late afternoon and early evening. During these times, there is a high energy use for heating domestic hot water that is used in taking showers. Currently, the warm shower water is collected and drained away using the sewer drainage system. There is no attempt to recover the heat from this waste stream.

#### **Solution**

Heat can be recovered from the sewer drainage system when soldiers are showering. This energy could then be used to preheat the shower cold water, which would reduce the hot water requirements. This can be accomplished by installing a shower drain heat recovery unit, which consists of a copper tube wound around the shower drain line for about 4 to 5 ft (1.2 m) in length (Figure 20). The installation of this heat exchanger requires special plumbing of the shower’s incoming cold water line. The cold water supply pipe must be connected directly to the heat exchanger so that the warmed cold water is immediately used by those taking showers. The use of this warmer cold water reduces the demand on the hot water flow.

Installing this heat recovery unit can be best done in conjunction with the construction of new barracks buildings. These new buildings are designed with shower rooms placed one above another such that the drain for all the showers in a vertical section could drain to the same vertical drain.

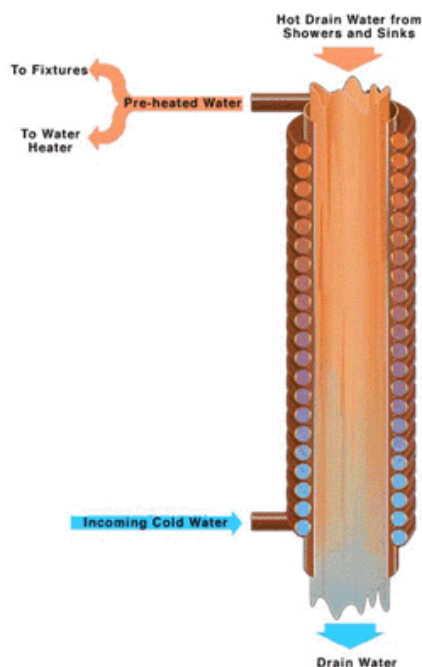


Figure 20. Shower drain heat recovery unit.

The shower heat recovery unit could be placed in the first floor wall where it could recover heat from the showers on floors above the first floor. The cold water for these showers would also be piped from this unit. It would be easy to install a shower drain heat recovery unit as part of the new building construction of the plumbing system. The first floor shower cannot be connected since the heat recovery unit works best in the vertical position and the drain from the first floor runs vertical in the ceiling space below the first floor. If this hot water heat recovery unit is not installed in the new barracks, the current inefficient system will continue to waste energy.

### Savings

It is estimated every soldier takes 1-½ 10-minute showers each day. The temperature rise of the hot water is from 60 °F (16 °C) to 140 °F (60 °C) or an 80 °F (44 °C) temperature rise. If the population in the barracks above the ground floor is 162 people, the heat recovery unit will save 25 percent of the hot water energy or 214 million Btu/yr (62,520 kWh/yr), so:

$$Q = 162 \text{ people} \times 1.5 \text{ shower/day} \times 300 \text{ days/yr} \times 10 \text{ min} \times 1.5 \text{ gal/min} \times 80 \text{ }^{\circ}\text{F} \\ \times 8.3 \text{ lb/gal} \times 0.25 / 0.85 \text{ eff.} = 214 \text{ million Btu/yr or } 62,520 \text{ kWh/yr}$$

$$\text{Energy cost savings} = 214 \text{ million Btu/yr} \times \$22.49/\text{million Btu} = \$4,813/\text{yr or } \text{€}3,975/\text{yr}$$

## **Investments**

The estimated cost to install a heat recovery unit on a 4-in. drain is \$1,000/drain (\$500 for the unit itself and \$500 for installation) assuming no unforeseen issues. Depending on the individual situation, the cost could be as high as \$3,000. Each pair of shower rooms are adjacent to each other and could share a common showers drain, which would be three stories high. There are approximately 15 shower drains required in the barracks building for a total cost of \$15,000 or €12,400.

## **Payback**

Simple payback will occur in 3.1 yrs.

## **HVAC #2. Gray water recovery**

### **Existing condition**

In the barracks there is a lot of water used for bathing that could be recovered and used for toilet flush water and for outside irrigation. This would reduce the total water used by the installation. This water could also be supplemented with captured rain water from building roofs.

### **Solution**

When designing and constructing the new building's plumbing system, place a non-potable water tank in the buildings lower level with a pump for the required water flow. Water used for showers and sinks could be drained to this tank. The rainwater off the roof could also drain to this tank. It is likely that some sort of treatment would be required, but that was not investigated. Water to be used in toilets and outside irrigation would be feed from this tank. The result would be a potable and non-potable water line run to each bathroom. There would also be two drains from these spaces – one that goes to the sanitary sewer and another to the storage tank on the lower level. If this water recovery unit is not provided in the new barracks design, then excessive water will be consumed by the operation of the barracks.

## Savings

Using Barracks number 170 as an example, there are 200 soldiers in residence. It is estimated that each soldier will take an average of 1.5 showers/day, which consume 25 gal (95 L) of water. The soldiers are present on the installation 300 days/yr. They will then use 2.37 million gal/yr or 8,970 m<sup>3</sup>/yr, therefore:

$$\begin{aligned}\text{Shower Water flow} &= 200 \text{ people} \times 1.5 \text{ shower/day} \times 300 \text{ days/yr} \times 10 \text{ min} \times 2.5 \text{ gal/min} \\ &= 2.25 \text{ million gal/yr}\end{aligned}$$

$$\text{Sink water flow} = 200 \text{ people} \times 2 \text{ gal/day} \times 300 \text{ days/yr} = 120,000 \text{ gal/yr}$$

$$\text{Total water flow} = 2.37 \text{ million gal/yr or } 8,970 \text{ m}^3/\text{yr}.$$

The cost of water is €0.6/ m<sup>3</sup> and the sewer costs is €0.46/m<sup>3</sup> for a total cost of €1.06/m<sup>3</sup>, therefore:

$$\text{Cost savings} = 8,970 \text{ m}^3/\text{yr} \times €1.06/\text{m}^3 = €9,500/\text{yr}.$$

## Investments

The estimated cost to the piping to collect the water, a 15,000 gal (56.8 m<sup>3</sup>) storage tank, and a pump is \$65,000 or €53,700.

## Payback

Simple payback will occur in 5.6 yrs.

## HVAC #3. Replace warm air heating system in vehicle maintenance areas with radiant heating, Bldg 2588

### Existing conditions

In the vehicle maintenance shops, warm air unit heaters are used to provide winter time building heating (Figure 21). These heaters contribute to temperature stratification in these spaces, which causes energy waste. Also, when large truck doors open it takes some time for the building temperature to return to normal.



Figure 21. Interior of Maintenance Facility with unit heaters

Since a specific building design is not available, a building that is 700 ft (213 m) long and 60 ft (18 m) wide will be used to demonstrate this ECM. The peak heating load is estimated to be 933,000 Btuh (273 KWh).

### **Solution**

In future constructed vehicle maintenance shops, the warm air heating design can be replaced with radiant heaters placed in the floor. These heaters will heat the floor, which in turn warms the people in those areas. Very little air stratification takes place and the infiltration of outside air has less cooling effect to the workspace. People working under vehicles will be comfortable since the floor will be warm.

The radiant heater will consist of piping that is placed in the floor with the concrete floor covering this pipe. Warm water heated by hot water from the central heating plant or a local boiler will be circulated through the in floor pipes. The amount of heat required will be controlled by area thermostats much like other heaters. If radiant floor heating is not used in the

future maintenance facility, excessive heating energy will be used and the occupants will not be as comfortable in the winter.

### **Savings**

It is estimated that radiant heating will save 20 percent of the energy used by a warm air heating system. Using a maintenance area of approximately 42,000 sq ft, the estimated annual heating energy use is 5,000 million Btu. The use of radiant heaters will save approximately 20 percent of this energy (based on a University of Stuttgart report, summarized in technical report ERDC/CERL TR-07-37) or 1,000 million Btu, which would be worth \$22,400/yr (€18,500/yr), therefore:

$$\text{Energy Cost Savings} = 1,000 \text{ million Btu/yr} \times \$22.41/\text{million Btu} = \$22,400/\text{yr}$$

Since the radiant heating system has fewer moving parts, it will have a lower maintenance cost of approximately \$5,000 (€4,100)/yr.

The total annual savings offered by the radiant system is \$27,400/yr (€22,600/yr).

### **Investments**

It is estimated that 21 unit heaters would be installed in this building, each having a capacity of 60,000 Btu (17.6 kW). The estimated cost to install these heaters with the associated piping, pumps, and controls is \$276,000 (€228,000). This included 21 60MBH unit heaters (\$76K), \$66K of piping, \$18.7 of pumps, and \$30.6K for valves and controls, plus 44 percent of that amount for various project costs. The estimated cost for a in-floor radiant heating system is \$348,000 (€287,000). This cost includes a pipe grid placed in the concrete floor, pumps and controls. The radiant floor heating system has an additional cost of \$72,000 (€59,000).

### **Payback**

The radiant floor heating system has an additional cost of \$72,000 (€59,000), but offers an annual cost saving of \$27,400 (€22,600) for a resulting simple payback of 2.6 yrs.

## **HVAC #4. Improved moisture control in barracks, Bldg 2102–2104 and 2109–2111**

### **Existing conditions:**

The recently constructed barracks, Bldgs 170 (Figure 22) and 173 have the type of HVAC system that the future barracks will have. The design of this system was reviewed and the following section contains suggestions for improvement. In general the design is quite good. There is a constant flow of tempered air to all rooms and a continuous exhaust of these rooms. Heat from the exhaust is transferred to the incoming supply air by heat recovery units in the attic. Room temperature control is maintained by fan coil units, one for each soldier suite (Figure 23).

The building is of a masonry construction. Each room contains a bathroom, sleeping area for two people, two closets, and a small kitchen area. The door into the room opens from the corridor and then are inner doors providing privacy to each bedroom and closet area.



Figure 22. Barracks Bldg 170.

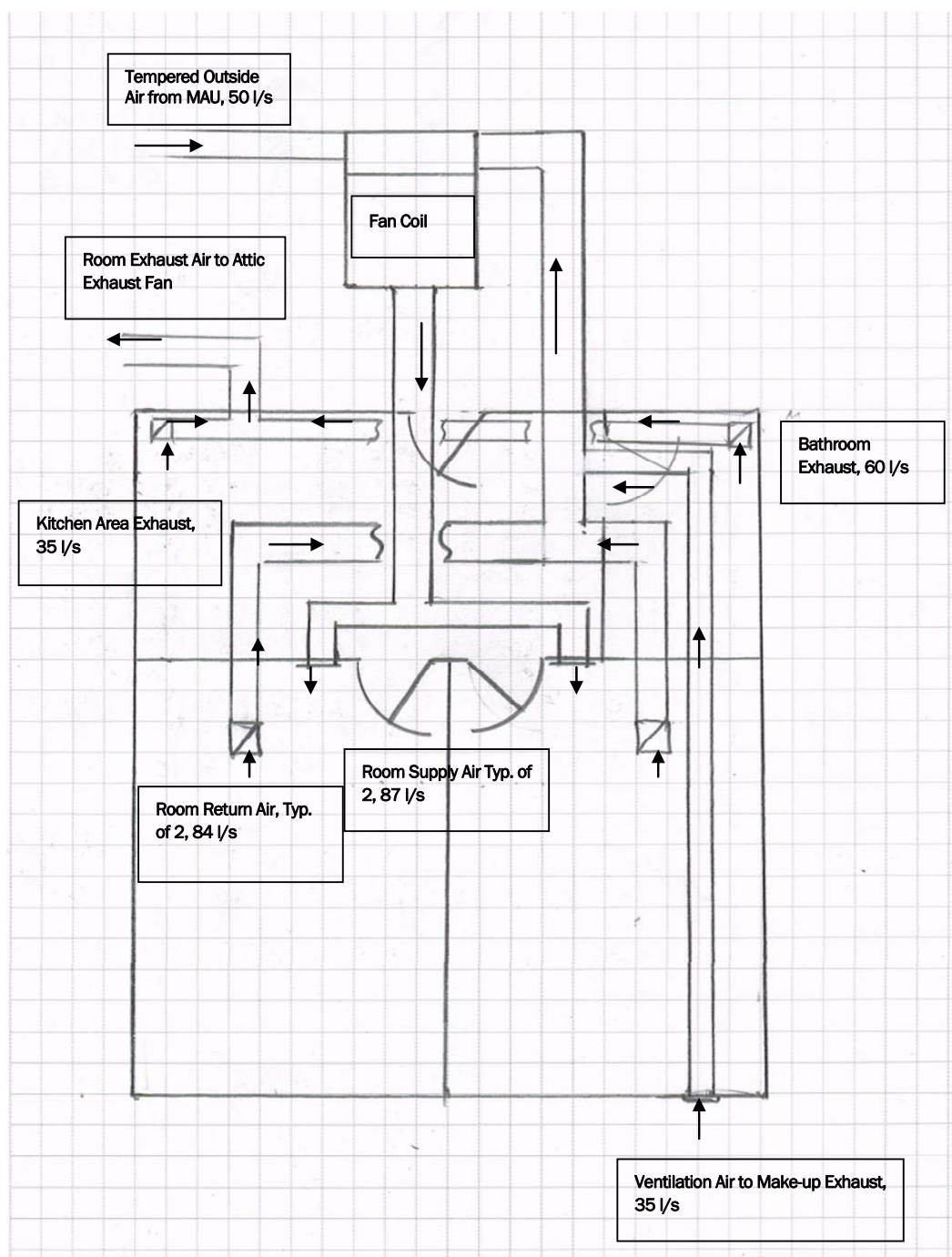


Figure 23. Typical 1 + 1 Soldier's room showing supply and exhaust air.

Each room has a fan coil unit to control the room temperature. The fan coil units use hot water and chilled water from the central chilled water plant for heating and cooling. The system is a four-pipe system and thus there are both heating and cooling coils in the fan coil unit. So the system can provide heating or cooling whenever there is heating hot water and

chilled water available from the central energy plant. Ventilation of the rooms is provided by a exhaust fans located in the attic space in each building wing. There are also two make-up air units in the attic space that provide tempered outside air to all the soldier rooms. Also in the attic space are heat recovery units to remove heat in the exhaust air and transfer it to the supply air.

The ventilation of a two person soldier suite on the first and second floor is as follows. The fan coil unit is in the ceiling space of the corridor adjacent to the room and it sends 184 CFM (87 L/s) into each soldier's room. There is return air of 178 CFM ( 84 L/s) from each room. There is a supply of 106 CFM (50 L/s) tempered outdoor air to each fan coil unit. Each suite has an exhaust of 127 CFM (60 L/s) from the toilet area. There is also a duct connection to an outdoor grille from the ceiling above the kitchen area, which is rated for an air flow of 74 CFM (35 L/s). The rooms on other floors have a similar ventilation scheme. Figure 23 shows this air flow.

Based on the site visit findings, the barracks have good control of the building temperature. There is no evidence of excessively humid conditions or mold growth. The HVAC equipment was easily accessible and appeared to be well maintained. One of the make-up air units was not operating because its fan belt was in the process of being changed. The building was in excellent shape and the windows fit tightly. The building controls were set up such that if a window was opened the space's AC system turns off. Since the building is a masonry construction it should be reasonable air tight and have little infiltration of outdoor air.

In the past couple years, an analysis was made on several similar barracks buildings. Part of this analysis was an evaluation using the blower door test to determine the soundness of the building structure to avoid infiltration. Such a test on these barracks showed that the outer wall and window system were tightly constructed. Unfortunately, there was significant leakage identified through openings leading to and in the pipe chase. In this shaft pipes run from the lower level of the building to the attic space above the upper floor. In one cast the lower level was a craw space with a dirt floor, which would be a source of moisture throughout the year. Building air tightness is a very important building requirement.

A moisture analysis of one of the barracks room having conditioned air supplied to it using a fan coil air-conditioner on a 2 percent design day shows the following potential moisture loads:

***Internal loads***

Showers in morning:	2.80 lb.
Brewing coffee in morning	1.30 lb.
Two people breathing, etc.	0.38 lb/hr
<i>Subtotal</i>	<hr/> 4.41 lb

***External loads***

Vapor Permeance	0.33 lb/hr
Infiltration thru walls (tight const.)	9.88 lb/hr
Ventilation air (74 CFM)	38.10 lb/hr
<i>Subtotal</i>	<hr/> 48.31 lb/hr
<b>Total</b>	<hr/> 48.31 lb/hr plus 4.1 lb

Moisture enters a barracks room by internal sources such as showers and people, and through infiltration, ventilation air, and the external building components. While the average length of showers is 8.2 minutes (Lawrence Berkeley National Laboratory [LBNL] report number 58601 entitled “Potential Water and Energy Savings from Showerheads” September 2005), the moisture analysis here assumes 15-minute showers because soldiers showering may be longer than average. The infiltration values are based on the infiltration provided by ASHRAE for tight construction. Excessive moisture results in mold growth that requires periodic costly clean-up of the barracks living quarters. It is common for Army installations to spend over \$1 million/yr removing mold.

Sites with central chilled water systems often have chilled water temperature entering the building’s supply air unit and fan coil units at 50 °F (10 °C) or above, which reduces the moisture removal of the fan coil units significantly. With a 50 °F (10 °C) chilled water temperature the leaving temperature from the supply air unit and fan coils is approximately 60 °F (16 °C). This air leaving the cooling coil will be almost saturated with water vapor approaching 100 percent relative humidity. The humidity ratio of this air is 78 grains per pound of dry air. If a room condition of 75 °F (24 °C) and 50 percent relative is desired, the corresponding humidity ratio is 66 grains per pound of dry air. This is humidity ratio lower than the

incoming air off the cooling coil and will not be achievable. With the moisture being added due to the above loads, the humidity in the soldier's room will be significantly higher than the desired 50 percent, probably approaching 70 percent relative humidity. At this humidity level, there will be locations that exceed 80 percent relative humidity, a condition that promotes mold growth.

### **Solution**

To minimize the conditions for mold growth, the barrack's living quarters must be of a tight construction that allows almost no infiltration of outside air. The shafts in the building must also be well sealed at openings to the living quarters and to the outside. The outdoor air brought into the building for ventilation and make-up for the exhaust system must be conditioned to a fairly dry state. The building occupants must be educated to avoid having windows open extensive periods of time during high humid conditions. It is understood that there are controls that shut off the room's HVAC whenever the windows are opened. This should result in few windows being open.

Another improvement to the current design is to greatly dehumidify the supply air brought into the building by the make-up air unit. The existing units use chilled water provided by the central chilled water systems. To accomplish this, the make-up AHU needs to have access to a very cold refrigerant or use a desiccant to properly dry the ventilation air. A direct expansion refrigeration unit can accomplish this extra cooling and the heat released by the condenser can be used to reheat this air so it is not too cold. The make-up air is currently ducted to each room, which is as it should be.

The fan coil units in each soldier room could continue to use chilled water and hot water generated by the local central heating and cooling plant. These units will be used to control the temperature of each room. Both the ventilation air and room fan coil units must be sized to handle the thermal and moisture loads. Calculations of these loads are required to properly size these units. Control of this equipment must be from a remote location and not by the occupants.

If good moisture control is not provided in the barracks rooms, there is a high likelihood that mold will be present.

### Savings

The first order of savings is reducing the potential for mold remediation costs. Having dryer air in the barracks will greatly reduce the presence of mold. Based on the experience at Fort Stewart (technical report ERDC/CERL TR-06-8),\* it is estimated approximately \$10,000 (€8,300)/yr can be saved in deferred mold clean-up costs.

A central control system would offer the opportunity to better maintain room temperatures. Overheating and overcooling could be minimized by monitoring the exhaust air temperatures and controlling the room temperature from that information rather than the setpoint on a thermostat. The building's supply AHUs can be used for temperature control during periods when the buildings are unoccupied and the fan coil units could be turned off. This occurs when the troops are out for the day and when they are off the installation for extended time periods. This occurrence is approximately 2 months/yr. Assumptions are: nine fan coils x 0.2 hp x 60 days/yr of fan motor savings plus an estimated 10 percent of the cooling energy use. The max chiller kW is 1170 kW x 1400 EFLH x 1 month out of 6 x 10 percent. This action would save approximately 19,000 kWh/yr in fan energy use and 27,000 kWh/yr for cooling energy saving, therefore:

$$\text{Electrical cost savings} = 46,000 \text{ kWh/yr} \times \$0.15044 / \text{kWh} = \$7,000/\text{yr} \text{ or } \text{€}5,700$$

There would also be a heating energy saving of approximately 110 million Btu/yr since the temperature could be set back during the times soldiers were not in the barracks, which is estimated to be 1 month during the winter. The soldier room fan coil units have a heating capacity of approximately 3,400 Btu heating (1 kW) It is estimated they would have heated at half this rate during the 1 month the barracks are unoccupied, therefore:

$$\text{Heating energy savings} = 90 \text{ rooms} \times 3,400 \text{ Btu/h} \times 50\% \times 30 \text{ days} \times 24 \text{ hrs/day} = 110 \text{ million Btu/yr or } 32,000 \text{ kWh/yr}$$

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\* John L. Vavrin et al. 2006. *Energy and Process Optimization Assessment: Fort Stewart, GA*. ERDC/CERL TR-06-8/ADA449505. Champaign, IL, Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), [http://www.ccer.army.mil/techreports/ERDC-CERL\\_TR-06-08/ERDC-CERL\\_TR-06-08.pdf](http://www.ccer.army.mil/techreports/ERDC-CERL_TR-06-08/ERDC-CERL_TR-06-08.pdf)

Fuel Oil Cost Savings = 110 million Btu/yr x \$22.41/ million Btu = \$2,500/yr or  
€2,060/yr

The total estimated annual savings of the ventilation and air tempering AHU approach is approximately \$9,500/yr or €7,760/yr.

### **Investments**

Using RS Means (construction data), the cost for adding the extra cooling unit to the make-up air units is estimated to be \$113,000 (€93,000).

Based on past experience, the controls to monitor the space temperatures and shut down fan coil units would be approximately \$40,000 (€33,000) for a total cost of \$153,000 (€126,000).

### **Payback**

The implementation of the dehumidification will ensure that healthy conditions are provided in the barracks. The project has a payback period of 7.9 yrs.

## **HVAC #5. Use of variable flow hot and chilled water systems**

### **Existing conditions**

From a review of recent building designs and observations of piping systems in the field the use of three-way valves at points of use is preferred at the Vicenza Garrison. Three-way valves are used with a constant flow distribution system (Figure 24). Hot or chilled water would flow from the boiler or chiller at the rate needed to satisfy peak demands by the HVAC equipment being served. At each AHU, some percentage of this flow would be diverted to the return piping system depending on the heating or cooling needs at the specific time. The result is that not all the energy is removed from the supply water and the return water temperature is closer to the supply water temperature than it needs to be.

The reason provided for a constant flow system at this installation is that the buildings farthest from the central energy plant will get the same temperature water as other buildings, the constant flow system helps with piping distribution problems and make system balancing easier. In general practice, these issues are overcome by a reverse return piping system de-

sign. With this design approach, the first user from the central energy plant is piped to be at the end of the return pipe system. The user that is last on the supply system has the shortest pipe run back to the central energy plant. Thus, the return of the closest user is piped to the point of return of the furthest user as shown in the sketch and the pipe loss of getting water to all users becomes approximately the same. This means all users require about the same pumping pressure and the balancing of water flow can be easily accomplished.

Constant flow systems are generally used with facilities that have rigid temperature control requirements such as some laboratories, clean rooms, and some manufacturing spaces where a slight temperature deviation affects the activities in the space. A constant flow system will provide a better assurance of receiving the desired water temperature.

Variable flow water distribution systems use two-way valves that stop and start flow at points of use such as air handlers. When the AHU's heating coil needs to warm the air the two-way valve opens to allow supply hot water to flow into the heating coil.

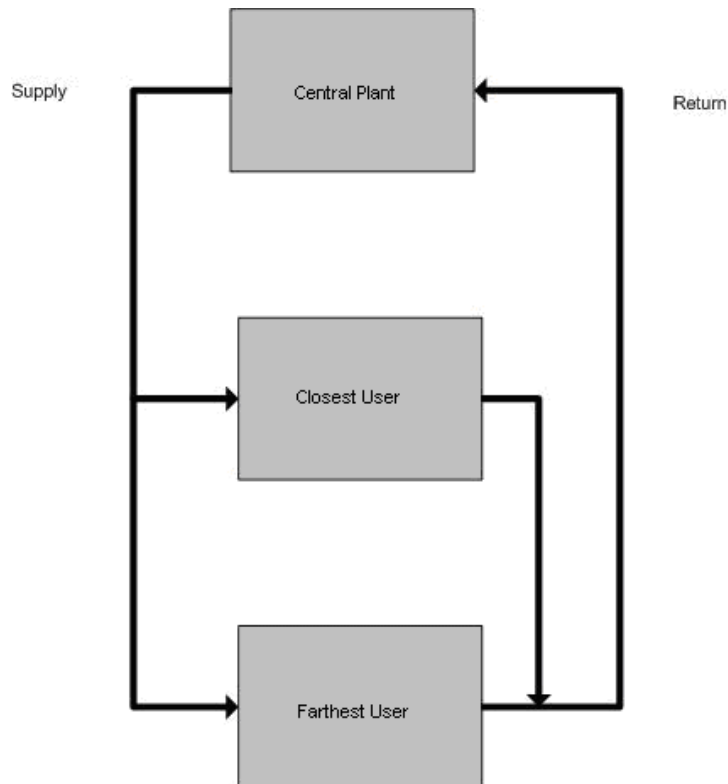


Figure 24. Constant flow system.

The initial water that flows through the valve will have lost some of its hot temperature since it has been sitting behind the valve for some time. But as flow from the hot water supply pipe enters the coil the hot water temperature quickly reaches the operating temperature, and full heating can be accomplished. This short delay is normally quite short and not noticed by the building occupants. To keep some water flowing through long branch lines off the main distribution line, the user farthest away is given a three-way valve to ensure water movement in the branch line.

The advantages of a variable flow system compared to a constant flow system is that pumping energy can be saved and fewer chillers may be required to operate. The variable flow system monitors the pressure in the supply water line and provides adequate pressure to ensure flow to the users that are farthest from the central plant. If less water is passing through the using equipment by closing the two-way valves, the pressure in the supply pipe will increase. This will be sensed by the pumping control system and the supply water pumps can reduce flow to the amount required. The reduced flow means less pumping energy is needed.

Typically, variable speed motors are used on these pumps to achieve the change in flow. Energy performance is helped by the reduction in flow resistance in the pipe distribution system as the rate of flow decreases. With less flow in a pipe the pressure loss in that pipe goes down and a lower pressure at the pump is needed to maintain the desired system pressures in the distribution pipe. This fact improves the energy savings of operating at less than full flow. Most building heating and cooling applications are at maximum heating or cooling demand for only a short percentage of the time of operation—typically less than 10 percent of the time. Since most of the time the demand is in the range of 30 to 70 percent of the peak, opportunity for the pumping energy savings exist.

Another energy use consideration is that boilers and chillers are designed for a narrow range of flow through them. Having a constant flow system requires a set number of this equipment to operate regardless of the heating or cooling load. This means more equipment would need to operate at a part load with a constant flow system. With a variable flow system, this equipment can be decoupled from the supply water system using a primary/secondary piping design. Here each boiler or chiller would have its own pump for constant flow through them (the secondary system). The

heated or chilled water would then flow into a pipe header of the distribution system (the primary system) where it would be sent out to all the buildings by the primary water pumps. This would enable the proper number of boilers or chillers to operate rather than having to operate more at inefficient load points.

If a constant flow chilled and hot water system is used, excessive energy use will result.

### **Solution**

Design the new hot and chilled water distribution systems to be variable flow. This will require replacing three-way valves currently in the buildings that will remain after the installation modernization. All new building should have two-way valves at all heating and cooling loads. The primary pumps that circulate the heating hot water and the chilled water will need a variable speed motor drive. Several pipe pressure monitors will need to be placed in the distribution system for proper pump control.

### **Savings**

Savings will result from reduced motor electrical energy use and lower energy loss in the distribution pipe system. The use of variable flow also works best with a thermal storage system since the return temperature is higher than with a constant flow system.

Based on past experience, flow can be reduced up to 80 percent of the current flow, which results in 50 percent savings in pumping power (power is a cubed function of flow), the estimated electrical savings for the pump operation is approximately half that of a constant flow system. The estimated pump horsepower is 60, therefore:

$$60 \text{ hp} \times 0.746 \text{ kW/hp} \times 8760 \text{ hrs/yr} \times 50\% = 196,000 \text{ kWh/yr}$$

$$\text{Electrical cost savings} = 196,000 \text{ kWh/yr} \times 0.15044/\text{kWh} = \$29,500/\text{yr} \text{ or } \text{€}24,400/\text{yr}$$

### **Investment**

The implementation costs should be minimal. The installation intends to put in a whole new system in the near future, so the costs used in this analysis are in addition to putting in a new system. The pump motors for the central energy plant hot and chilled water system must be a variable

speed type. For a 60 hp motor, this would be an added cost of approximately \$13,000 (€10,700) per motor for a variable speed drive. The cost of two-way valves compared to three-way valves will be less. A 3-in. two-way valve has a cost of approximately \$770 (€640) compared to a cost of \$1,350 (€1,110) for a three-way valve. The piping cost with a three-way approach is more since an additional pipe is required for the connection between the return water pipe and the supply water pipe. The variable flow system will also have an extra control costs for monitoring pipe pressure. It is estimated that the cost for six monitoring locations should be no more than \$15,000 (€12,400). The cost of all the pipe connection associated with a three-way valve system plus the extra valve cost will greatly outweigh the cost of the variable speed motors and the required controls.

The total estimated cost of the variable speed motors and pressure sensing controls is \$41,000 (€33,900) minus whatever the valve cost savings would be.

**Payback:**

The resulting payback would probably be immediate since the valve savings would be greater than \$41,000. Using the \$41,000 cost as a worst case, the payback period is 1.4 yrs.

## **HVAC #6. Enable economizer operation for cooling**

**Existing conditions/problems**

Most of the chillers at Ederle Caserma were *Off* during the assessment week since the site visit occurred in March and the chillers for AC reasons are not switched *On* until Mid-May. In Bldgs 10 (dining facility and Air Force Network [AFN]) and 302 (PX); however, the chillers were partly running (Figure 25).

AFN contains the radio and TV broadcasting studios and equipment, which (according to installation personnel) require the chillers to be running. In the PX, the various AHUs supplied air into the building with a large variety of supply air temperatures. There is no reason to do this. Diffusers within the PX shopping area and the food court could supply 25 °C (77 °F) air adjacent to diffusers that supplied 17 °C (63 °F) air. This means that the building was simultaneously heated and cooled.



Figure 25. Typical chiller at Ederle Caserma.

This energy wasting situation is made worse by chillers that were run to provide cooling although the Outdoor Air temperature was only 12 °C, which would have been good enough to mix with some return air and get the desired supply air temperature of 17 °C. Meanwhile, the AHU supplying 25 °C should be adjusted to supply the same temperature as the other AHUs, thus saving also on the heating costs.

The Siemens Building Control system of AHU1 in Bldg 302 indicates the following conditions:

- return air temperature was 21.8 C (71 °F)
- return air damper indicates 100 percent closed
- outdoor air damper indicates 100 percent open
- outside air temperature was 12.0 °C (54 °F)
- cooling valve was 57.3 percent open
- supply air temperature was 14.9 °C (59 °F).

This leads to the conclusion that the OA damper is 100 percent closed (not open) and the return air (RA) damper is 100 percent open (not closed). That is the only reasonable explanation to how it is possible to get the 14.9 °C Supply Air (SA) temperature with the cooling valve more than half open.

Regarding the storage area in the back regions of PX, the supply air temperature was 27 °C (81 °F) and the space temperature was 23 °C (73 °F), *with the large cargo doors open.*

In the AFN case, the operation of the chillers and the AHUs was not investigated more thoroughly, but the use of economizing functions, i.e., using as much free cooling as possible from the outside air before allowing chillers to start operating, would likely be appropriate there as well.

### **Solution**

Check all the AHUs in Bldgs 10 and 302, preferably as a part of a general re-commissioning of building controls and HVAC systems, with respect to:

- damper function and operational sequences to allow maximum use of both free cooling and free heating
- controls and their programming so that the sequences are right, i.e., free cooling used to its maximum before any chiller is allowed to start.

Consider installing switches at the PX cargo doors that whenever a door is open, sends a signal to the HVAC controls to close the heating or cooling control valves completely, to avoid unnecessarily venting heating or cooling to the open air.

Adjust setpoints so that AHUs supplying the same spaces work towards the same space temperature, thus avoiding simultaneous heating and cooling.

### **Savings**

Assume that two of the large AHUs at PX, at 20,000 m<sup>3</sup>/h each, run without the economizer operation working, thus unnecessarily forcing the chiller to run to cool RA from 22 to 15 °C during October – May, 8 months, when free cooling could have been used instead. Also, assume COP of chillers to be 3.0 so that:

$$20,000 \text{ m}^3/\text{h} = 5.6 \text{ m}^3/\text{s}. \text{ Two units means a total air flow of } 11.2 \text{ m}^3/\text{s}.$$

Energy used for cooling is then:

$$11.2 \text{ m}^3/\text{s} \times 1.2 \text{ kJ}/\text{kg} \cdot ^\circ\text{C} \times 7 ^\circ\text{C} \times 8 \text{ months} \times 30 \text{ days} \times 24 \text{ hrs} / 3.0 = 180,600 \text{ kWh},$$

worth €22,500/yr.

Savings in Bldg 10 are estimated to be half of the above calculated savings, or \$14K/yr.

Savings by adjusting setpoints are more fully discussed in ECM HVAC-7 (p 69).

Switches at cargo doors can save huge amounts of heating and cooling energy depending on how often and how long the doors are open. The savings are not possible to calculate at this stage. Instead, an example of savings from another U.S. Army installation (Rock Island Arsenal [RIA]) is discussed below:

The savings depend on the frequency of the opening and closing cycles of a door. A large heated warehouse, with a door that is 12x12 ft, open 10 min/hr, causes heat losses of over 1,400 kWh/day or 170 MWh/yr. In RIA the cost of providing steam to make up for those heat losses is \$1,360. Triple the time in open position and triple the size of the door and the annual cost is over \$12,000/yr.

Savings for a large door, 20 by 18 ft (open 30 min/hr):

1,250 MWh at \$8/MWh = \$10,000/yr

Rock Island has *very* low heating energy costs compared to Ederle Caserma. On the other hand, the Vicenza climate is milder than in Rock Island, IL, which reduces the heating costs, but the savings by switching heat off whenever doors are open are still substantial.

Savings from reduced cooling costs can be added to the heat savings also regarding the open cargo doors.

### **Investment**

The required investment will be less than €10,000 for functionality checks and re-programming existing controls.

### **Payback**

Simple payback will occur within 0.3 yr.

## **HVAC #7. Increase/decrease space temperature setpoints and make them uniform**

### **Existing conditions/problems**

Throughout the installation a large variation of actual space temperatures and space temperature setpoints were observed. The highest space temperatures were found in Bldg 311, with 29 °C (85 °F). Equal conditions were also found in Bldg 108, with 28 °C (82 °F). Most buildings have AHUs with far too high temperature setpoints or get heated by hot water circulating through radiators, although no heat was required (see also ECM HVAC-4, p 55). The chillers were not yet in operation; therefore, no observations could be made regarding cooling season temperatures. The present situation, with high space temperatures, is very energy consuming and also substantially reduces productivity.

### **Solution**

Make a general written statement, signed by the garrison commander, that the lowest acceptable space temperature setpoint during the cooling season is 76 °F and for the heating season no more than 70 °F. At the same time, make sure that these setpoints are included in the Installation Design Guide for all new projects and also for all future renovation/modernization projects. Adjust all setpoints for space temperature according to the statement. Establish a routine for spring and autumn for Department of Public Works (DPW) personnel to check setpoints and adjust them for heating and cooling seasons respectively. If deemed necessary: Lock all thermostats in locked cages, where only the respective building managers have the key. This means taking the controls out of control from the individuals working in the building. In buildings that are connected to the EMCS, update all setpoints to match the new limits.

### **Savings**

The savings by lowering the temperature setpoints will be calculated on a per square foot basis and for both the heating and the cooling season:

Assume a 10,000 sq ft building with a 10-ft ceiling, i.e., 100,000 cu ft volume; air supply 10,000 cfm with 30 percent outdoor air, 3,000 cfm (=1.42 m<sup>3</sup>/s). Then, increase space temperature (and also supply air temperature)

by 10 °F (5.5 °C) in the summer; Chiller COP = 3.0; Reduce space temperature by 10 °F (5.5 °C) in the winter. Cooling savings, AHU are:

$$1.42 \text{ m}^3/\text{s} \times 1.2 \text{ kJ/kg } ^\circ\text{C} \times 5.5 \text{ } ^\circ\text{C} \times 26 \text{ wks} \times 168 \text{ hrs} / 3.0 = 13,650 \text{ kWh}$$

Cooling savings from reduced transmission losses vary according to building design, construction, and installation quality, but can, on the average, be assumed to be at least as high as the savings from the AHU, or another 13,650KWh.

At \$0.15044/KWh this equates to \$4,108/yr (€3.4 K), so that heating savings AHU are:

$$1.42 \text{ m}^3/\text{s} \times 1.2 \text{ kJ/kg } ^\circ\text{C} \times 5.5 \text{ } ^\circ\text{C} \times 26 \text{ wks} \times 168 \text{ hrs} = 41 \text{ MWh (140 MMBtus),}$$

worth \$2.1K (€1.7 k).

Heating savings from reduced transmission losses also vary according to building design, construction and installation quality, but can, on the average, be assumed to be at least as high as the savings from the AHU, or another \$2.1K.

Total savings then are approximately \$8.3K/yr, or \$0.83/sq ft/yr. With 100,000 sq ft of buildings where this situation occurs and where changes should be made, the total savings are \$83 k/yr.

### **Investment**

Required investment will be less than €1,000 for a 10,000 sq ft building, all related to (DPW) labor costs; total investment for 100,000 sq ft is €10,000

### **Payback**

Simple payback will occur within 0.2 yrs.

## **HVAC #8. Local radiator thermostats to prevent overheating**

### **Existing conditions/problems**

During the assessment, it was obvious that something was quite wrong throughout the installation regarding temperature control, energy waste and overheating of spaces. Since the visit took place in mid-March, no chillers were running (fortunately enough), but the heating system was

still *On* and would remain on until switched *Off* in the middle of May when also the chillers are switched *On*.

In radiators and fan coil units, there was a constant circulation of hot water. There are valves on each radiator/ fan coil so that the heat circulation can be switched off manually by the person sitting in the room (Figure 26), but those were not easily accessible. The manual dampers (Figure 27) are not enough to keep the heat out of the room, even if they are closed.



Figure 26. Manual radiator valve.



Figure 27. Radiator unit.



Figure 28. Open windows in Bldg 108.

The result was that many rooms were very hot and in many cases the windows were opened to expel the heat. Figure 28 shows this condition in Bldg 108, the Family Readiness Center.

Since the AHUs in some buildings have far too high setpoints, the situation is even worse, with two sources of overheating. The energy waste is substantial and the indoor temperature is much too high to be good for productivity.

### **Solution**

It is proposed that the manual valves to each radiator and fan coil (where there is no external sensor and regulating valve to control the heat) be replaced by a magnetic valve and a wall-mounted thermostat in each room. The thermostat should be set at the indoor temperature that is decided (see ECM HVAC-7, p 69), and will automatically switch off the heat circulating through the radiator or fan coil when there is no need for heat. If there is more than one radiator in a room, the thermostat must be set up to switch off all the radiators in the room, e.g., in conference rooms.

For some buildings, like Bldg 207 (the Motor Pool), a modified solution is proposed: When no heat is needed, switch off the heat circulation pump in the heat exchanger “box” outside the building to stop heat from circulating through all unit heaters at the ceiling.

**Savings**

Savings regarding energy are estimated to be at least €50/room and year; improved productivity will lead to even better payback. It is estimated that this solution could be applied to at least 200 rooms. Annual savings then (on energy only) add up to €10k.

**Investment**

Required investments are estimated to be approximately €100/room with one radiator, €150 with two radiators in a room. On average, with most rooms only having one radiator or fan coil, the estimated investment is €110/room or €22k in total for 200 rooms.

**Payback**

Simple payback will occur within 3.2 yrs. (This estimated does not take improved productivity into consideration.)

**HVAC #9. Install heat recovery from refrigeration systems at the Commissary, Bldg 290****Existing conditions/problems**

At present, there is a heat recovery system for condenser heat installed in the Commissary. The heat is intended to be used to heat domestic hot water. During the visit, however, no heat was recovered. This is due to the fact that the Commissary these days does not use very much hot water, since the circumstances have changed and there are no longer any big end-users of hot water. Therefore, the heat is cooled off in the air-cooled refrigerant coolers on the roof (Figure 29).

**Solution**

Add a circuit to the existing system so that heat can be recovered through a heat exchanger that circulates air in the storage, back area, of the commissary. This means that close to half of the building can be heated by using the excess heat from the refrigeration systems. This building will apparently also stay in place during the entire Master Plan period, which makes the investment worthwhile.



Figure 29. Air-cooled refrigerant coolers on the roof.

### **Savings**

Bldg 290, the Commissary, is supplied by the central heating system and since it is on the North side, in the steam system. From metered data (Energy Brain) it is understood that this building uses approximately 2,750 MMBtus for heating annually. By being conservative and saying that the savings will be 40 percent of the annual heat used, this ECM will save 1,100 MMBtus worth \$19K/yr.

### **Investments**

Required investment will be less than €30,000 if piping is minimized, i.e., the heat exchanger between the recovered heat and the circulating air is placed just outside the wall of the refrigeration mechanical room. A more detailed study or initial design would have to be performed to determine the specifics of the heat exchanger, piping, hot water tank, etc.

### **Payback**

Simple payback will occur within 1.9 yrs.

## **HVAC #10. Re-commission building controls and replace pneumatic controls with DDC**

### **Existing conditions/problems**

Existing building controls are not in the condition that they once were and that they need to be to have AHUs, boilers, chillers, perimeter heat systems etc. work as they should do. Sequences of operation are not accurate with respect to the way buildings and spaces are used today. Setpoints for temperature and air flow need to be revised. Control functions that once were active are not active any more, e.g., regarding economizing modes with outdoor and return air dampers in sequence and according to initial design and construction. See examples of the above mentioned in other ECMs. Signals from temperature, static pressure, and other sensors are not calibrated. Many systems are controlled by pneumatic controls. Although some may prefer pneumatic systems, they are less accurate than DDC controls and also require air compressors, which also use electric energy and need maintenance, which increases the operating costs.

A typical EMCS consists of a central computer and many measurement and control points that activate or modulate fans, dampers, pumps, coils, chillers, boilers and other HVAC equipment. Programmed into that system are many schedules (at Ederle Caserma no night or weekend temperature set-backs are done from EMCS, as far as we could see), sequences of operation and control schemes designed to maintain comfort while trimming energy costs. For savings to occur, however, not only must the programming be correct (without conflicts, such as simultaneous heating and cooling), but all measuring devices (e.g., temperature sensors) and actuators must be working as designed. As with links in a chain, failure at one level makes the rest essentially irrelevant.

When an EMCS is installed, it is usually tested to ensure it will deliver comfortable conditions, but its operation may not be verified for optimal energy efficiency. An EMCS needs to be commissioned on installation or retro commissioned thereafter to ensure it will deliver promised savings. An EMCS and its control points need to be retro commissioned if it has:

- unusually high energy use
- chronic failures of building equipment, the control system, or both
- numerous and growing comfort problems.

## **Solution**

Get back to original specifications and design. Compare to what the building used to be used for and make re-design to match today's needs and occupancy level/type of use of the building. Choose only such buildings that have a remaining life expectancy of 5 yrs or more. Check every signal, every function, and validate that the functions are available. If not, fix whatever needs to be fixed. Make sure simultaneous heating and cooling can never occur, by programming new sequences and blocking use of units that can cause the simultaneous heating and cooling. Set alarm points for important signals such as high temperatures, low temperatures, damper failure, pressure too high or too low etc. Troubleshoot all the AHUs and their respective functions (log dampers, temperatures, actuator signals, and other parameters) to identify problems. Adjust chiller and boiler set-points and control curves. Replace malfunctioning hardware and adjust software. Implement night and weekend temperature setback. Optimize economizer modes/cycles. Check variable air volume (VAV) boxes, variable frequency drives (VFDs), pressure sensors and controls.

More specific things to fix should also include:

1. Insulating pipes and duct work. Temperature increases in summer and temperature drops in winter are not negligible.
2. Repair or replace all failing equipment, e.g., non-operating dampers, controls out of control; 100 percent OA instead of 100 percent RA. Figure 30 shows a nonfunctional damper control and missing metal link and damper motor at Bldg 108.
3. Adjust building air and water flows to designed values.
4. Upgrade controls to DDC at most buildings and heat exchanger "boxes" and connect to EMCS



Figure 30. Nonfunctional damper control, missing metal link and the damper motor at Bldg 108.

### **Savings**

Savings from proper commissioning or later retro commissioning will range widely, depending on how well systems were designed, installed, and maintained prior to review. Independent studies have shown cuts in energy costs ranging from 3 to 50 percent with paybacks for commissioning ranging from 3 months to 5 yrs. In the case at Ederle Caserma, with more than just normal retrocommissioning (points 1, 3, and 4 must be seen as additional work), the savings will be in the upper range.

### **Investment**

Due to variations among buildings and systems, costs for commissioning or retro commissioning services vary widely, from \$0.03 to \$0.43/sq ft, with \$0.20/sq ft being a generally accepted average, see "Building Operation Management," January 2007, pages 49 -52. That cost typically encompasses review of all EMCS programming, testing of all measurement and control points, identification of all problems, minor repairs and a short-term verification of savings. With points 1, 3, 4, and 5 the investments will also be in the upper range, as the savings.

### **Payback**

Simple payback will occur in less than 5 yrs.

Table 11. Summary of HVAC ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
HVAC #1	Shower gray water heat recovery	0	0	\$—	214	\$3,172	\$—	\$3,172	\$15,000	4.7
HVAC #2	Gray water recovery	0	0	\$—	0	\$—	\$—	\$11,624	\$65,000	5.6
HVAC #3	Replace warm air heating system in vehicle maintenance areas with radiant heating, Bldg 2588	0	0	\$—	1,000	\$22,410	\$5,000	\$27,410	\$72,000	2.6
HVAC #4	Improved moisture control in Barracks, Bldgs 2102 – 2104 and 2109 – 2111	46,000	0	\$6,920	110	\$2,465	\$10,000	\$19,385	\$153,000	7.9
HVAC #5	Use of variable flow hot and chilled water systems	196,000	0	\$29,486	0	\$—	\$—	\$29,486	\$41,000	1.4
HVAC #6	Enable economizer operation for cooling	90,300	0	\$13,585	0	\$—	\$—	\$13,585	\$10,000	0.7
HVAC #7	Increase/decrease space temperature setpoints and make them uniform	27,300	0	\$4,107	280	\$4,150	\$—	\$8,257	\$26,600	3.2
HVAC #8	Local radiator thermostats to prevent overheating.	0	0	\$—	0	\$—	\$—	\$—	\$26,638	—
HVAC #9	Install heat recovery from refrigeration systems at the Commissary, Bldg 290	0	0	\$—	1,294	\$19,181	\$—	\$19,181	\$36,324	1.9
HVAC #10	Re-commission Bldg controls and replace pneumatic controls with DDC	0	0	\$—	0	\$—	\$—	\$—	\$—	—
<b>Totals</b>		<b>399,600</b>	<b>0</b>	<b>54,098</b>	<b>2898</b>	<b>51,379</b>	<b>15,000</b>	<b>144,208</b>	<b>\$445,562</b>	<b>3.0</b>

## 8 Lighting (LI)

Several opportunities for lighting were found, the principal ones being controls and daylighting.

### LI #1. Provide light sensors for spaces with natural light

#### Existing conditions/problems

There are spaces within buildings that well lit by daylight from outside through skylights and/or windows. Despite that, the lights inside the building are *On*. The use of artificial lights inside during these periods of the day does not make it any brighter inside than the daylight does. Therefore this is only a waste of energy. During the heating season, it is also more expensive to heat the space by turning on the lights than it is to use heat from the central heating system. During the cooling season the use of lights unnecessarily increase the energy used for cooling if cooling is available; otherwise the lights contribute to space temperatures higher than desired.

Examples of buildings where lights were on when they just as well could have been switched off:

- Bldgs 2, 3, 300 (part of Cafeteria close to windows)
- School Gym
- 207 Maintenance
- PX entrance and PX spaces with 24 skylights.

Figure 31 shows the school gym where up to 1,000 Lux was measured.

Figure 32 shows the stairwell in Bldg 2, with bright sunshine in through the glass blocks and the lights on in the ceiling.

#### Solution

Install light sensors that switches sets of interior, artificial lights *Off* when the light levels are enough, for example above 300 Lux (28 foot-candles). Also, at the same time, install timers that do not allow these lights to be on at night in unoccupied spaces.

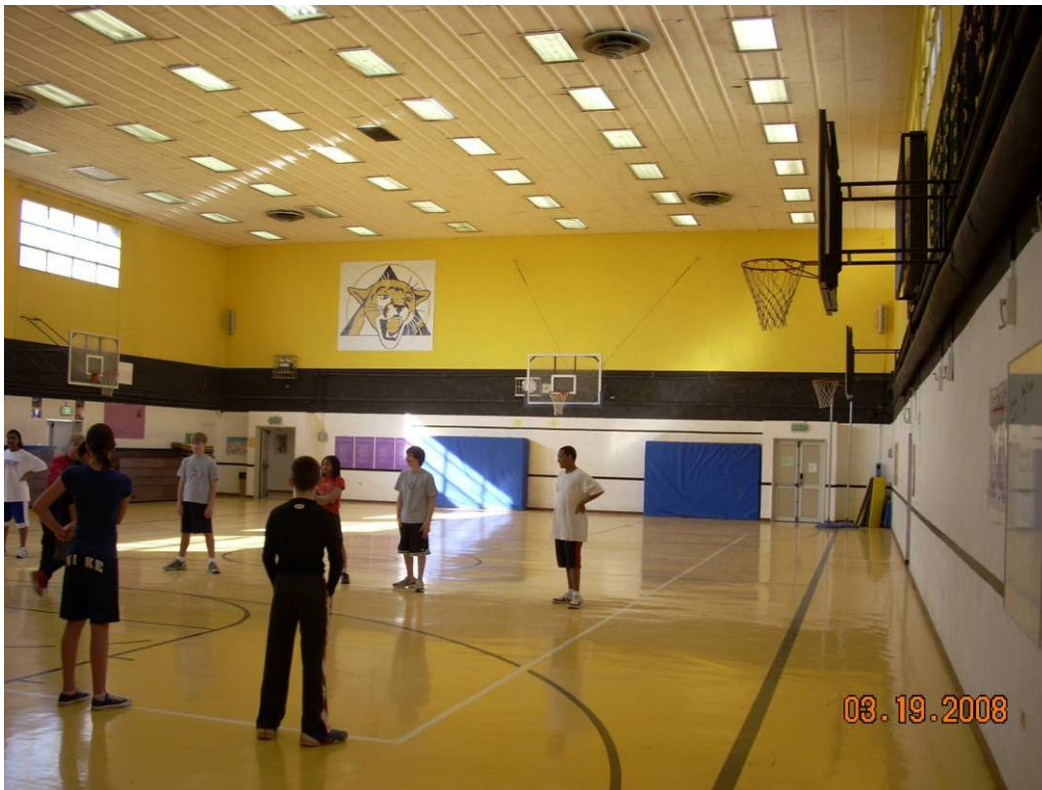


Figure 31. Bright sunshine in school gym.



Figure 32. Bright sunshine in Bldg 2 stairwell.

## **Savings**

The savings are illustrated by an example from the school gym, Bldg 309. In the ceiling there are 66 fixtures with four, 4-ft fluorescent tubes in each. Assume that the tubes are T8s, at 36W each. During normal days these lights will not need to be *On*, other than at periods when the daylight is reduced due to clouds, rain etc. On normal days it will probably be possible to reduce the operating hours for these lights by 8 hrs/day, 5 days/wk, therefore:

Energy savings:  $(66 \times 4 \times 36W) \times 8 \text{ hrs/day} \times 5 \text{ days} \times 52 \text{ wks} = 19,768 \text{ kWh/yr.}$

Savings occur at daytime, when the on-peak electricity charge is applicable (\$196.2/MWh), so that:

Value of savings:  $19.8 \text{ MWh} \times \$196.2/\text{MWh} = \$3,878.$

For the other buildings mentioned above the annual savings will be less, depending on how many fixtures to be controlled, but the investment cost is probably similar in all cases. Therefore, the school gym is the prime candidate for this ECM, thereby followed by, in order, Bldgs 302 (PX), 207, 300, 2, 3.

## **Investment**

Two light sensors and two timers installed and commissioned will cost \$1K

## **Payback**

Simple payback will occur within 0.3 yr.

## **LI #2. Solar tubes**

### **Existing conditions/problems**

Ederle Caserma has some buildings with few or no windows to let daylight in. This makes electric energy for lighting a major operating cost of these buildings. Examples of such buildings are the Commissary warehouse, 290, and the warehouse part of PX, Bldg 302.

**Solution**

Install so called “Solar Tubes” that direct the daylight into the buildings so that the existing, energy-consuming, lights can be switched off when daylight is sufficient. This should be the case in most of the hours that these buildings are being used and occupied.

**Savings**

The solar tubes are intended to be installed in parts of Bldgs 290 and 302.

We presume that lights are switched off when people do not occupy the buildings. Otherwise the savings will be higher.

**Bldg 290 savings:**

100 fixtures with  $2 \times 36\text{W} \times 8 \text{ hrs/day} \times 260 \text{ days/yr} = 15,000 \text{ kWh/yr}$ .

At \$196/MWh (€162/MWh) the savings are worth \$2.9K.

Avoided costs for maintenance, light bulb changes etc., estimated at \$1,200 (€1,000/yr), give total savings of \$4.1K.

Bldg 302 savings are in the same range as the Commissary savings, which give total savings of \$8.2K

Additional savings: Improved lighting standards (some parts are very dark today with artificial lights).

**Investment**

Required investments are:

- Bldg 290: \$21K (€35 k)
- Bldg 302: \$21K (€35 k).

The investment costs are very preliminary and will not be known until a partial design is performed.

**Payback**

Simple payback will occur in 5 yrs.

### LI #3. Install occupancy switches in certain spaces

#### Existing conditions/problems

Some spaces are unnecessarily lit when no one is in or near the space. Examples of such spaces are: Conference rooms (e.g., Room 046 in Bldg 108 i.e., the Army Community Service [ACS] classroom), bathrooms, offices. Also refrigerated cases in the Commissary and the Shoppette and the walk-in cooler in Shoppette would benefit from occupancy sensors. Figure 33 shows refrigerated cases for frozen products at the Commissary.

Figures 34 and 35 show the Shoppette walk-in cooler (18 doors at the right) from outside and inside.



Figure 33. Refrigerated cases for frozen products at the Commissary.



Figure 34. Shoppette walk-in cooler (outside).



Figure 35. Shoppette walk-in cooler (inside).

### *Solution*

Install either:

- Replace the light switch with an infrared wall-mounted occupancy sensor. When someone enters the room, the lights switch *On*. When the room has been empty for an adjustable time period, the lights switch *Off*.
- In refrigerated cases: Install a switch in the door that switches the lights *On* when the door is opened and vice versa.
- In the walk-in cooler: Replace the light switch with an infrared wall mounted occupancy sensor, as above.

### *Savings*

The ACS classroom has 14 fixtures with four 18W tubes in each, i.e., a total of 1 kW. Assume that the lights are *On* unnecessarily during 6 hrs/day, 5 days/wk, therefore:

$$\text{Savings (Lights)} = 1 \text{ kW} \times 6 \times 5 \times 52 = 1,560 \text{ kWh/yr}$$

In addition to this, excessive heat must be cooled *Off* during 20 wks. Assume a COP for the chiller of 3.0, therefore:

$$\text{Savings (Chiller)} = 1 \text{ kW}/3.0 \times 6 \times 5 \times 20 = 200 \text{ kWh}$$

Extrapolating to offices, class rooms and conference rooms that are 20 times the ACS classroom:

$$\text{Total Savings (20 rooms)} = 35,200 \text{ kWh}$$

The Shoppette walk-in cooler has four fixtures with 36W tubes in the ceiling and 18 fixtures with 36W tubes by the doors, for a total of 800W. Assuming the possibility to save on lighting during at least 12 hrs/day (more here since the Shoppette is open 24/7):

$$\text{Savings (walk-in cooler lights)} = 0.8 \text{ kW} \times 12 \times 7 \text{ days} \times 52 \text{ wks} = 3,500 \text{ kWh}$$

$$\text{Savings (walk-in cooler cooling)} = 0.8 \text{ kW}/3.0 \times 12 \times 7 \times 52 = 1,160 \text{ kWh}$$

The refrigerated cases in the Commissary (for frozen food) each have a 58W fluorescent tube plus one tube per set of cases (covering all ends). Cold food cabinets each have three rows of 4-ft, 36W tubes. Assume 30 frozen food cabinets (six sets with five doors) and 30 cold food cabinets.

Total electric load then is  $6 \times (5+1) \times 58\text{W} + 30 \times 3 \times 36\text{W} = 5.3 \text{ kW}$ . Installing switches to have these lights switched *Off* during 6 hrs/day, 6 days/wk:

$$\text{Savings (refrig case lights)} = 5.3 \text{ kW} \times 6 \times 6 \times 52 = \sim 10,000 \text{ kWh/yr}$$

In addition to this, excessive heat must be cooled *Off* during all 52 wks. Assume a COP for the chiller of 3.0, therefore:

$$\text{Savings (refrig case cooling)} = 5.3 \text{ kW} / 3.0 \times 6 \times 6 \times 52 = 3,300 \text{ kWh}$$

Total savings in the Commissary and Shoppette then is around \$10K annually.

#### *Investment*

The cost to install an infrared wall mounted occupancy sensor where the lighting switch is located is approximately €200 each. Total investment to cover the savings calculated above is estimated to be around €6,000.

The investment for the Shoppette walk-in cooler (a combination of occupancy sensor and door switches) is estimated to be around €600.

The investment at the Commissary, only door switches, is calculated to be around €20/door or €1,200.

The total investment this is around \$9.4K (€7,800)

#### *Payback*

Just under 1 yr.

Table 12. Summary of lighting ECMs

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Elec Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
LI #1	Provide light sensors for spaces with natural light	19,768	0	\$3,878	0	\$—	\$—	\$3,878	\$1,000	0.3
LI #2	Solar tubes	30,000	0	\$5,886	0	\$—	\$2,400	\$8,286	\$42,000	5.1
LI #3	Install occupancy switches in certain spaces	53,160	0	\$10,430	0	\$—	\$—	\$10,430	\$9,444	0.9
<b>Totals</b>		<b>102,928</b>	<b>0</b>	<b>20,194</b>	<b>0</b>	<b>0</b>	<b>2,400</b>	<b>22,594</b>	<b>52,444</b>	<b>2.3</b>

## **9 Miscellaneous Low Cost/No Cost Energy Savings Opportunities**

### **Misc #1 Miscellaneous low/no cost**

#### **Existing conditions/problems and solution**

Most units or systems that showed serious malfunctions were reported in the 21Mar08 outbrief, but are described here with proposed solutions:

1. Replace nonfunctional actuator for the heat control valve on the large Bldg 311 rooftop AHU so 49 °C air is not constantly discharged into the space.
2. Change space temperature setpoints for AHUs in Bldg 108 (from 25 °C to 20 °C) and also in Bldg 311. See also ECM HVAC-7 (p 69).
3. Clean/replace OA filter in the small AHU, Bldg 108 (Figure 36) so that OA can enter the AHU. At present the air flow may be close to zero.
4. Switch off the heat to Bldg 7 A and B (barracks). The building is empty and rooms are being renovated, but the heat is left on while doors are left open.
5. Repair and use curtains at refrigerated cases in Commissary (Figure 37). The curtains are in place, but inoperable (investigators did not dare put much pressure on them; they might have broken). These curtains save large amounts of energy input to refrigeration units if used at all hours when the commissary is closed. Freezers should be covered, if covers exist.
6. Install thermostats (replace manual on/off switches) for all unit heaters in 207.

#### **Savings**

Most of these actions are maintenance and service related. Savings can at this stage only be estimated, to around €5,000 annually, most of which from switching off heat, installing thermostats and fixing the curtains. Savings from 1 and 2 above are already included in previous ECMs.

#### **Investment**

The estimated cost to resolve problems related to 3–6 is €3,000.

#### **Payback**

Simple payback will occur within 0.6 yrs.



Figure 36. OA filter in the small AHU in Bldg 108.



Figure 37. Refrigerated case in Commissary.

Table 13. Summary of miscellaneous ECMs.

ECM Description	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Elec Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
	(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
Miscellaneous low/no cost	0	0	\$—	0	\$—	\$—	\$6,054	\$6,054	1.0
<b>Total</b>	<b>0</b>	<b>0</b>	<b>\$—</b>	<b>0</b>	<b>\$—</b>	<b>\$—</b>	<b>\$6,054</b>	<b>\$6,054</b>	<b>1.0</b>

## 10 Renewables

Several opportunities for renewables were investigated including a solar wall and photovoltaic solar panels. The potential favorable price paid for renewable electrical generation makes this a very attractive opportunity.

### REN #1. Solar wall

#### Existing conditions

Buildings that have few windows and outside walls that would receive a lot of sunlight could be heated using solar energy (e.g., Figure 38). These buildings include maintenance shops, storage facilities and some service buildings. For this ECM analysis, an example building will be used that is a maintenance shop having a approximately 50 m (164 ft) of tall wall on the south side with a clear section of 4 m (13 ft) high. The size of this solar wall will be 186 m<sup>2</sup> (2000 sq ft) in size. The building's ventilation system will operate through the entire heating season.



Figure 38. Facility at Vicenza that is a candidate for a solar wall.

## Solution

The use of solar energy is desired for this facility. The type of solar collector proposed is called a solar wall (Figure 39). A solar wall is a perforated wall placed a few inches outside of the buildings wall that receives a significant amount of sunlight. The sunlight heats the wall. Air is pulled from the cavity between the perforated wall and the building wall, which causes air to be drawn through the small openings in the outer wall. As air passes through the outer wall, it is warmed. This solar heated air is brought into the building for use as ventilation air. In addition to the solar heat captured, this wall also recovers heat that is conducted through this wall due to the temperature difference between inside and outside. Failure to use a solar wall on these buildings would result in a excessive heating energy use.

## Savings

Based on a computer load simulation of this application over the heating season, this solar wall will capture 308 million Btu from the sun and 29 million Btu will be recovered from building conduction losses. The total energy saved 337 million Btu or 98.7 mWh of thermal energy is:

$$\text{Heating energy cost savings} = 337 \text{ million Btu/yr} \times \$22.41 / \text{million Btu} = \$7,600 / \text{yr or} \\ \text{€6,300}$$



Figure 39. Example building with solar wall.

### Investment

The cost of this solar wall is \$21.40 (€17.67)/sq ft installed. An avoided cost of \$6 (€4.96)/sq ft is available for avoided cladding costs. This makes the solar wall have a net cost of \$15.40 (€12.72)/sq ft for a cost of \$30,800 (€25,400). The cost of the duct system that takes the collected warm air to the building ventilation unit is estimated to be \$0.50/CFM. Since the collector air flow is 13,000 CFM (6,100 L/s) this cost is \$6,500 (€5,400). Add a contingency of 10 percent the total cost becomes \$41,000 (€33,900).

### Payback

Simple payback will occur in 5.4 yrs.

## REN #2. Photovoltaic Bldgs 1, 2, 3

### Existing conditions

In Caserma Ederle, Vicenza seven buildings are evaluated to install PV-Systems on it. These seven buildings are enduring buildings because in the Vision Master Plan only these seven buildings will remain all other buildings will be reconstructed or replaced by new buildings.

The basic calculation factors for the funding are defined in a specific Italian program called “Nuovo Conto Energia Fotovoltaico.” The reference Italian regulations are: “Decree (DM) 19/02/2007” and “Resolution of the AEEG (Autorità per L'Energia Elettrica ed il GAS) n. 90/07.”

The funding are differentiated based on the size of the PV-System and the architectural integration. For PV-Systems with more than 20 kW, the following funding are valid:

1. Not integrated/free-standing = €0.36/kWh
2. Partially Integrated = €0.40/ kWh
3. Fully Integrated = €0.44/ kWh.

In the following calculations for roof-mounted PV-Systems No. 2 (Bldgs 1, 2, 3, 170, 173, 290), and for free-standing PV-Systems, No. 1 (Bldg 290) will be used to calculate the results. In both cases, the PV-Modules of Würth Solar will be used.

The prices as shown in the orientation quotation of Part 1 will be used, although in the papers of DPW Vicenza, an investment price of \$4,700/kW is estimated. At the current exchange rate, this is ~€3,182/ kW.

Both investment estimates are used in the detailed calculations to show the differences in the results caused by the different investment estimates.

In case of realization, the investment price scenario has to be checked.

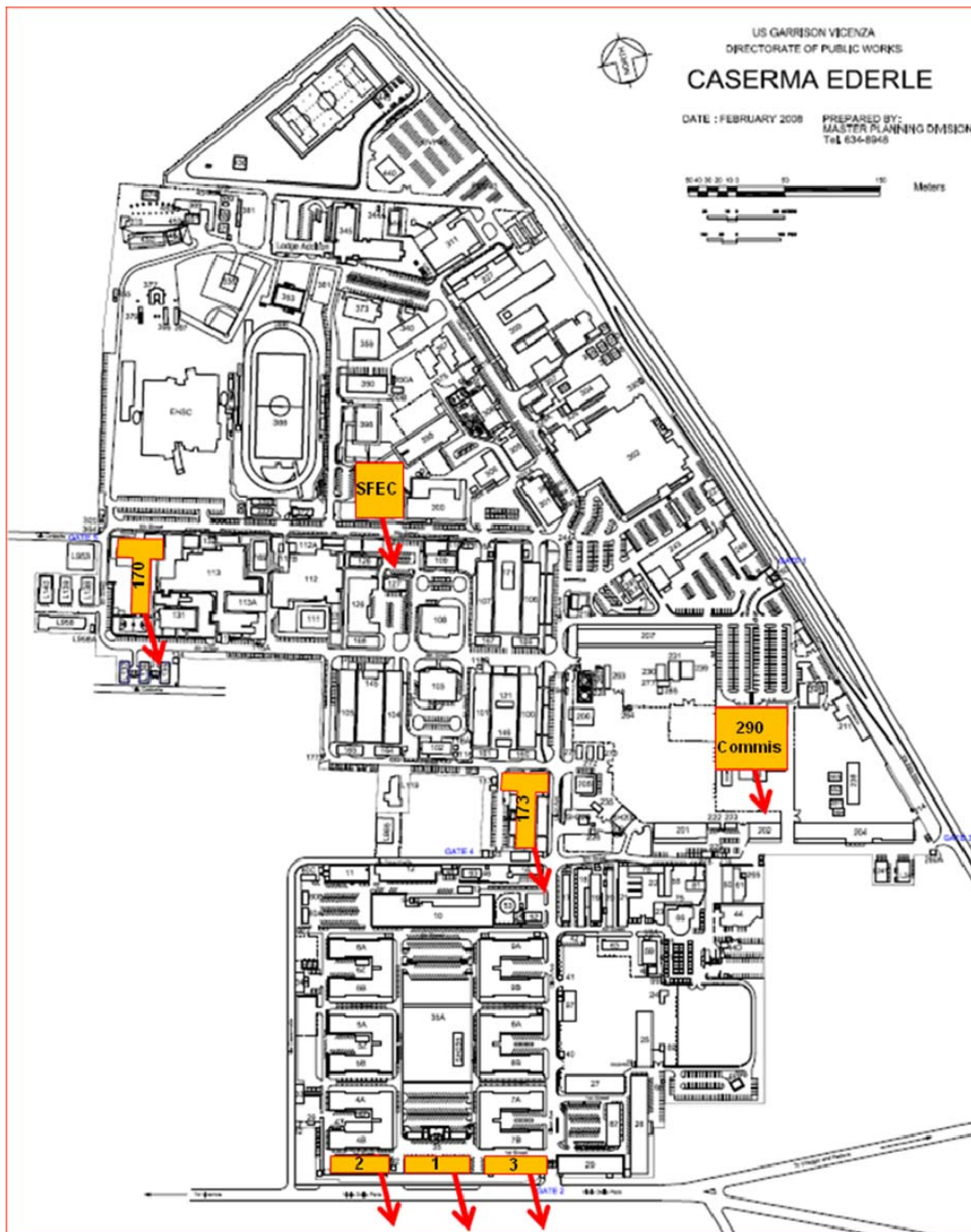
There is no Open Space in Vicenza for free-standing ground-placed PV-Systems.

All calculations are to be seen as orientations within a bandwidth of +/- 5 percent.

Cable length, specific construction issues, inclination data, PV-areas of the roof, the number of modules are in some cases estimated figures and due to these estimates the results per building may change within this bandwidth.

The site plan the buildings, which are evaluated are marked.

The Master Plan shows the development of Caserma Ederle in the next 15 years (Figure 40). The enduring buildings marked in the Site Plan Vicenza (Figure 41) as appropriate for PV-Systems are marked in the Master Plan Vicenza and also to point out why only these seven buildings are selected for PV-Systems.



**Figure 40. Caserma Ederle Site Plan with marked buildings.**

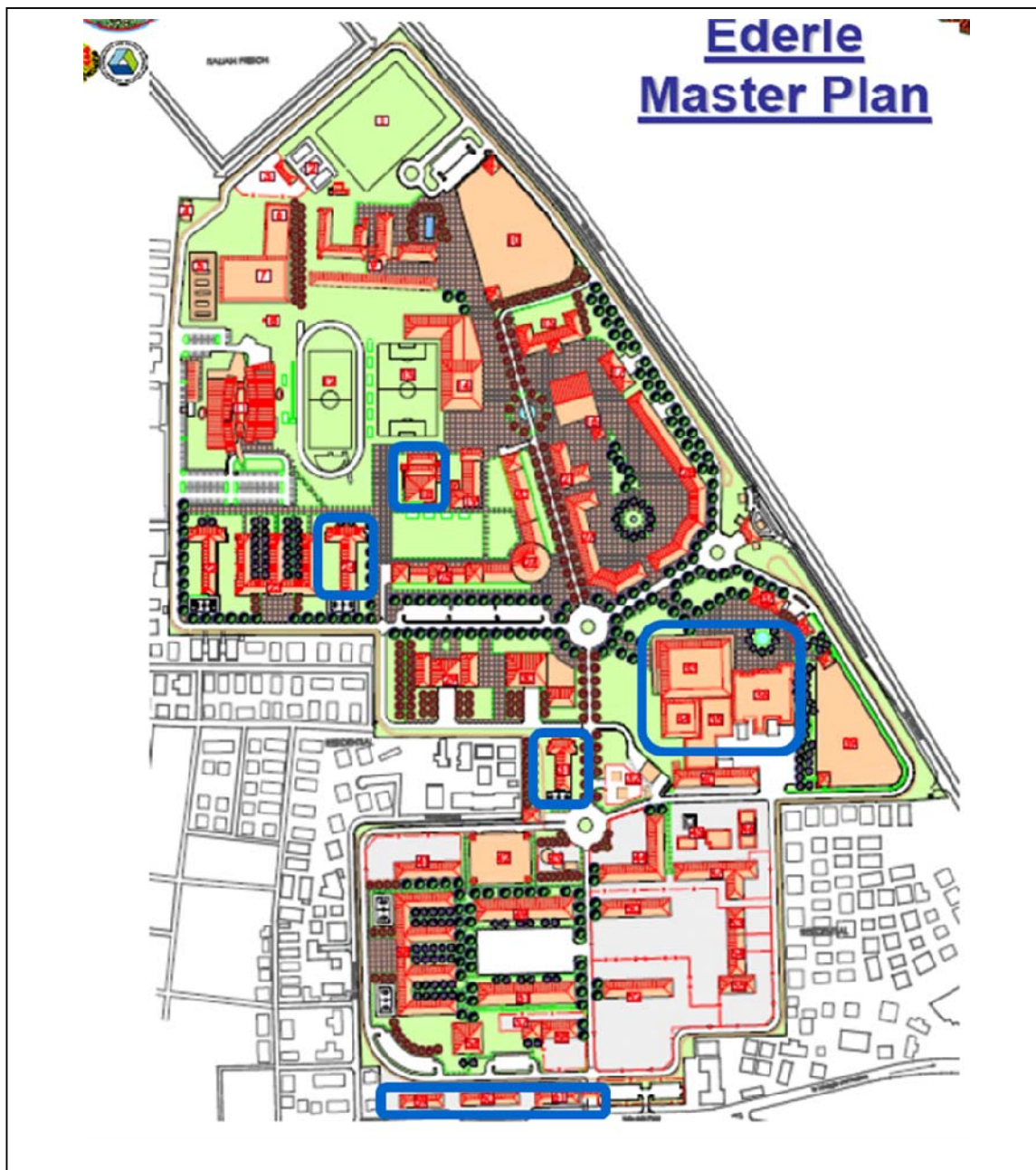


Figure 41. Vision Master Plan Caserne Ederle with enduring buildings.



Figure 42. Bldg 1, 2, 3, Office – Vicenza.

Bldgs 1, 2, and 3 are nearly identical in construction (Figure 42):

- All three roofs are hipped end roofs.
- The foot prints are slightly different.
- The orientations are identical = 195 degrees.
- The PV-Systems tend towards the city.

For all three buildings, a PV-System of the same size was calculated. The actual size may differ slightly according to the slightly different sizes of the roofs.

### Solution

Table 14. Bldg 1, 2, 3 PV-systems – Vicenza.

Bldg	1, 2, 3	Remarks
Location	Vicenza	
Footprint (approx)	45 m x 12 m	
Roof characteristic	Hipped Roof	
Inclination (approx)	20 degrees	
Orientation	195 degrees	
Area of PV-system	240 m <sup>2</sup>	
No. of modules	340	
Output	27.37 kW (Peak)	
Roof load/m <sup>2</sup>	17.5 kg	

Bldg	1, 2, 3	Remarks
Estimated yearly results		
Specific annual yield	1.247 kW/kWp	
Grid feed-in/yearly	34,131 kWh	First year/Degradation: 5% in 20 yrs
Total revenue (20-yr period)	266,657 €	Installation End 2008
Total revenue (20.5-yr period)	273,483 €	Installation Mid 2009
Investment cost	124,424 €	Total Investment costs including installation
Investment cost/kWp	4,546 €	
Break even time (without capital cost) German investment €/ kW estimate	9/9 yrs	Installation 2008/2009
Break even time (without capital cost) Italian investment €/ kW estimate	6/6 yrs	Installation 2008/2009
Liquidity cumulated (with capital cost)	€83,550/€90,376	Installation 2008/2009
Real rate of return German investment €/ kW estimate	67.1%/72.6%	Installation 2008/2009
Real rate of return Italian investment €/ kW estimate	159.0%/166,8%	Installation 2008/2009
CO <sub>2</sub> Reduction cumulative	220 tons/226 tons	Installation 2008/2009

### Payback

The values in the two grey marked frames show the differences between the results of the two different investment estimates:

€4,546/ kW (German price):

Breakeven = 9 yrs

Real return of return = approx. 70%

€3,182/ kW (Italian price):

Break even = 6 yrs

Real rate of return = approx. 165%

Note that the DPW Vicenza calculation shows a breakeven of about 5.9 yrs.

## REN #3. Photovoltaic SFEC Building

### Existing Conditions



Figure 43. SFEC Building.

Table 15. SFEC building PV System.

Bldg	SFEC	Remarks
Location	Vicenza	
Footprint (approx)	—	
Roof characteristic	Ridge Roof	
Inclination (approx)	20°	
Orientation	195°	
Area of PV-system	900 m <sup>2</sup>	
No. of modules	1,250	
Output	100.63 kW (Peak)	
Roof load/m <sup>2</sup>	17.5 kg	
Estimated yearly results		
Specific annual yield	1.271 kW/kWp	
Grid feed-in/yearly	127,928 kWh	First year/Degradation: 5% in 20 yrs
Total revenue (20-yr period)	999,482 €	Installation End 2008
Total revenue (20.5-yr period)	1,065,067 €	Installation Mid 2009
Investment cost	457,464 €	Total Investment costs including installation
Investment cost/kWp	4.546 €	

Bldg	SFEC	Remarks
Break even time (without capital cost) German investment €/ kW estimate	9/9 yrs	Installation 2008/2009
Break even time (without capital cost) Italian investment €/ kW estimate	6/6 yrs	Installation 2008/2009
Liquidity cumulated (with capital cost)	€326,262/€351,847	Installation 2008/2009
Real rate of return German investment €/ kW estimate	67.1%/72.6%	Installation 2008/2009
Real rate of return Italian investment €/ kW estimate	165.0%/172.9%	Installation 2008/2009
CO <sub>2</sub> Reduction cumulative	825 t/846 t	Installation 2008/2009

## REN #4 Photovoltaic Barracks Bldgs 170, 173

### Existing conditions— Bldgs 170, 173 (Barracks)

On Bldgs 170 and 173 (Figure 44) only the south-oriented roofs are appropriate to put PV-Systems on it. The larger parts of the roofs have a west-east orientation, which is not applicable for PV-Systems.

No drawings of the roof characteristics were available. Figure 44 shows the estimated number of PV-modules.



Figure 44. Bldgs 170, 173, Barracks — Vicenza.

Table 16. Bldgs 170, 173 PV-Systems – Vicenza.

Bldg	170, 173	Remarks
Location	Vicenza	
Footprint		
Roof characteristic	Hipped Roof	
Inclination (approx)	200	
Orientation	1950	
Area of PV-system (approx)	100 m <sup>2</sup>	
No. of modules	130	
Output	10.47 kWp	
Roof load/m <sup>2</sup>	17.5 kg	
Estimated yearly results		
Specific annual yield	1.272 kW/kWp	
Grid feed-in (yearly)	13,321 kWh	First year/Degradation: 5% in 20 yrs
Total revenue (20-yr period)	104.077 €	Installation End 2008
Total Revenue (20.5-yr period)	106.741EUR	Installation Mid 2009
Investment cost	47,597 €	Total Investment costs including installation
Investment cost (kWp)	4.546 €	
Breakeven time (without capital cost) German investment €/ kW estimate	9/9 yrs	Installation 2008/2009
Breakeven time (without capital cost) Italian investment €/ kW estimate	6/6 yrs	Installation 2008/2009
Liquidity cumulated (with capital cost)	€34.032/ 36.696 €	Installation 2008/2009
Real rate of return German investment €/ kW estimate	71.5%/77,1%	Installation 2008/2009
Real rate of return Italian investment €/ kW estimate	165.2%/173,2%	Installation 2008/2009
CO <sub>2</sub> reduction cumulative	86 t/88 t	Installation 2008/2009

There was no information of the value of the funding for PV-Systems with a lower PV-output than 20 kW. Therefore the value of the PV-Systems with an output > 20 kW is used in the calculation.

## REN #5 Photovoltaic Commissary Bldg 290

### Existing Conditions—Commissary Bldg 290

No roof plan was available (just a floor plan). Therefore the area necessary for the devices on the roof could not be checked. The PV-System (Figures 45 and 46) was designed based on the estimate that approximately 4800 m<sup>2</sup> of open space would be available on the commissary roof.



Figure 45. Bldg 290, Commissary – Vicenza

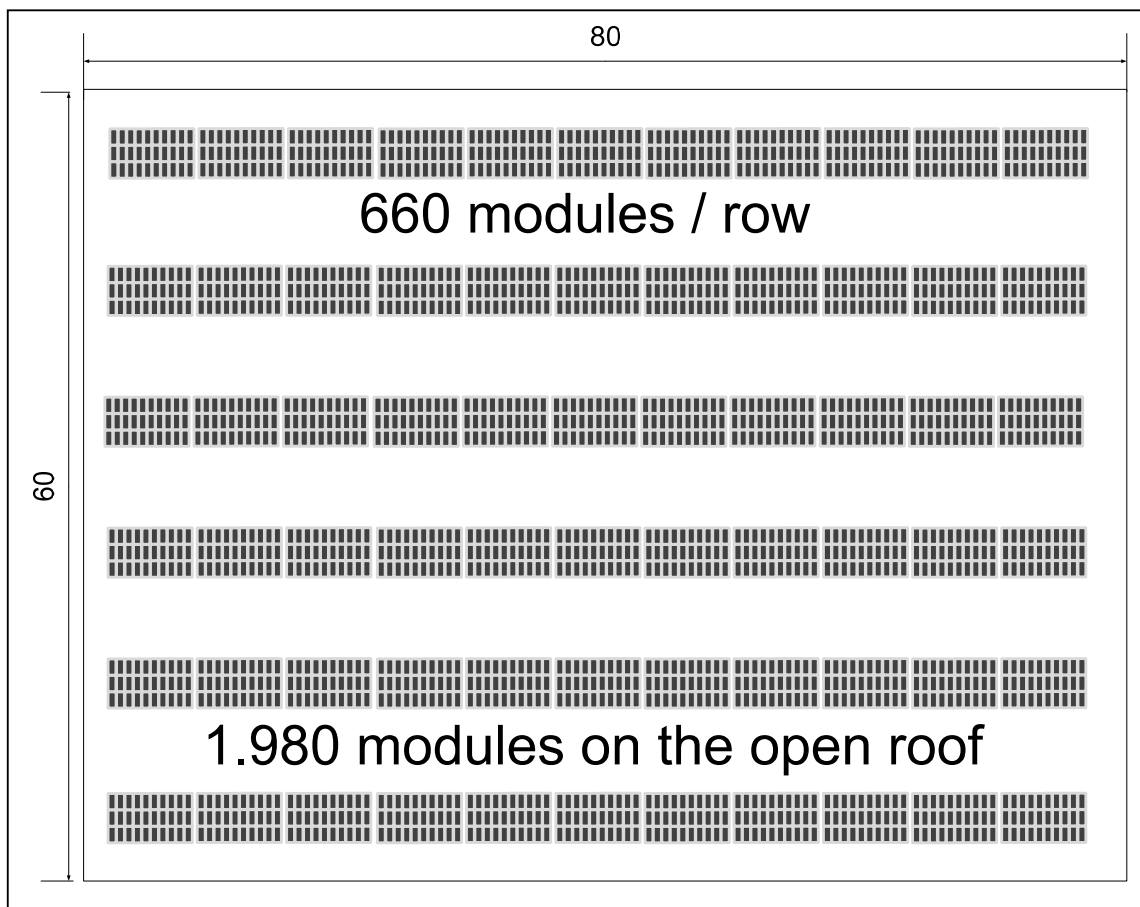


Figure 46. Bldg 290, Commissary – Positioning PV-System

Table 17. Bldg 290 Commissary PV-System – Vicenza.

Bldg	290, Commissary	Remarks
Location	Vicenza	
Footprint (approx)	—	
Roof characteristic	Flat Roof	Free-standing PV-System
Inclination (approx)	35 degrees	
Orientation	180 degrees	
Area of PV-system	1.426 m <sup>2</sup>	
No. of modules	1.980	
Output	159.39 kWp	
Roof load / m <sup>2</sup>	19.25 kg	10% mark up because of carrier system
<b>Estimated yearly results</b>		
<b>Specific Annual Yield</b>	<b>1.307 kW/kWp</b>	
Grid feed-in / yearly	208,346 kWh	First year / Degradation: 5% in 20 yrs
Total revenue (20-yr period)	1.464.992 €	Installation End 2008
Total revenue (20.5-yr period)	1.502.494 €	Installation Mid 2009
Investment cost	760,816 €	Total Investment costs including installation
<b>Investment cost / kWp</b>	<b>4.773 €</b>	5% mark up because of carrier system
Break even time (without capital cost) German investment €/ kW estimate	10/10 yrs	Installation 2008/2009
Break even time (without capital cost) Italian investment €/ kW estimate	7/7 yrs	Installation 2008/2009
Liquidity cumulated (with capital cost)	€345.348/ 382,850 €	Installation 2008/2009
Real rate of return German investment €/ kW estimate	45,4%/50,3%	Installation 2008/2009
Real rate of return Italian investment €/ kW estimate	127,9%/135,8%	Installation 2008/2009
CO <sub>2</sub> Reduction cumulative	1,343 t/1,377 t	Installation 2008/2009

Table 18. Summary of renewable ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Total Savings: Elec Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)			
REN #1	Solar wall	0	0	\$—	337	\$7,552	\$7,552	\$41,000	5.4
REN #2	Photovoltaic Bldgs 1, 2, 3	34131	0	\$16,530	0	\$—	\$16,530	\$150,653	9.1
REN #3	Photovoltaic SFEC Building	127928	0	\$61,958	0	\$—	\$61,958	\$457,464	7.4
REN #4	Photovoltaic Barracks Bldgs 170, 173	13321	0	\$6,452	0	\$—	\$6,452	\$47,597	7.4
REN #5	Photovoltaic Commissary Bldg 290	208346	0	\$100,906	0	\$—	\$100,906	\$760,816	7.5
<b>Totals</b>		<b>383,726</b>	<b>0</b>	<b>\$185,846</b>	<b>337</b>	<b>\$7,552</b>	<b>\$193,398</b>	<b>\$1,457,530</b>	<b>7.5</b>

## **11 Summary, Recommendations, and Lessons Learned**

### **Summary**

This work conducted an Energy Optimization Assessment at Caserma Edlerle as a part of the Annex 46 showcase studies to identify energy inefficiencies and wastes and to propose energy-related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13423 and EAct 2005. The study was limited to a Level I assessment. The scope of the study included an analysis of building envelopes, ventilation air systems, controls, interior and exterior lighting, and an evaluation of opportunities to use renewable energy resources.

The study identified a total of 28 different potential energy conservation measures (ECMs), which are summarized in Table 19. Table 20 categorizes the ECMs into: Building Envelope, Central Energy Plants, Controls, Dining Facilities, HVAC, Lighting, Miscellaneous, and Renewables. If all these ECMs were implemented, they would result in approximately \$750K savings/yr (1,702 MWh/yr in electrical energy savings, 12,922 MMBtu/yr in thermal savings (mostly fuel oil), in addition to \$37K/yr in maintenance savings. Implementation of these projects would require an additional investment of \$309K and will yield an average simple payback of 0.4 years. A major reason for this relatively small investment requirement is the credit for avoided capitol costs of the central energy plant and distribution systems.

The installation is undergoing many changes, the most significant of which is the demolition of a large portion of the existing facilities and construction of new ones. The detailed schedule that specifies which buildings are to be demolished at what time are included in the installation's Master Plan. This makes energy savings opportunities on the existing facilities difficult. Still, many opportunities were identified that have a very quick payback, and it is recommended that they be pursued. In addition, some facilities are not slated to be demolished until several years in the future. These should be pursued first.

Table 19. Summary of all ECMs.

ECM #	ECM Description	Electricity Savings		Thermal			Maintenance \$/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint \$/yr	Investment \$	Simple Payback Years
		(MMBtu/yr)	(KWh/yr)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
BE #1	Establish a cool roofs strategy (for all re-roofing projects and for new constructions)	28	8,318	\$1,251	11	\$157		\$1,408		0.0
CEP #1	Thermal storage system	0		\$51,000		\$0		\$51,000	-\$120,000	-2.4
CEP #2	Future district heating system as a hot water system	-512	-150,000	-\$22,566	4,096	\$53,000	\$20,000	\$50,434	-\$1,589,000	-31.5
CON #1	Fix/replace HVAC controls	0		\$0	1,247	\$19,089		\$19,089	\$12,108	0.6
CON #2	Reduce HVAC run time/schedule AHUs to match building occupancy	3,120	914,510	\$137,579	7,706	\$114,217		\$251,795	\$18,000	0.1
CON #3	Consolidate HVAC control systems	0		\$0		\$0		\$0		-
DIN #1	Modify kitchen hoods with end skirts, Bldg 745	140	41,000	\$6,168	235	\$5,266		\$11,434	\$6,000	0.5
DIN #2	Variable flow kitchen hoods	143	42,000	\$6,318	488	\$10,936		\$17,255	\$26,400	1.5
HVAC #1	Shower gray water heat recovery	0		\$0	214	\$3,172		\$3,172	\$15,000	4.7
HVAC #2	Gray water recovery	0		\$0		\$0		\$11,624	\$65,000	5.6
HVAC #3	Replace warm air heating system in vehicle maintenance areas with radiant heating, Bldg 2588	0		\$0	1,000	\$22,410	\$5,000	\$27,410	\$72,000	2.6
HVAC #4	Improved moisture control in Barracks, Bldgs 2102 – 2104 and 2109 – 2111	157	46,000	\$6,920	110	\$2,465	\$10,000	\$19,385	\$153,000	7.9
HVAC #5	Use of variable flow hot and chilled water systems	669	196,000	\$29,486		\$0		\$29,486	\$41,000	1.4
HVAC #6	Enable economizer operation for cooling	308	90,300	\$13,585		\$0		\$13,585	\$10,000	0.7
HVAC #7	Increase/decrease space temperature setpoints and make them uniform	93	27,300	\$4,107	280	\$4,150		\$8,257	\$26,600	3.2
HVAC #8	Local radiator thermostats to prevent overheating,	0		\$0		\$0		\$0	\$26,638	-
HVAC #9	Install heat recovery from refrigeration systems at the Commissary, Bldg 290	0		\$0	1,294	\$19,181		\$19,181	\$36,324	1.9
HVAC #10	Re-commission building controls and replace pneumatic controls with direct digital control (DDC)	0		\$0		\$0		\$0		-
LI #1	Provide light sensors for spaces with natural light	67	19,768	\$3,878		\$0		\$3,878	\$1,000	0.3
LI #2	Solar tubes	102	30,000	\$5,886		\$0	\$2,400	\$8,286	\$42,000	5.1
LI #3	Install occupancy switches in certain spaces	181	53,160	\$10,430		\$0		\$10,430	\$9,444	0.9
MISC #1	Miscellaneous low/no cost							\$6,054	\$6,054	1.0

ECM #	ECM Description	Electricity Savings		Thermal			Maintenance \$/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint \$/yr	Investment \$	Simple Payback Years
		(MMBtu/yr)	(KWh/yr)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
REN #1	Solar wall	0		\$0	337	\$7,552		\$7,552	\$41,000	5.4
REN #2	Photovoltaic Bldgs 1, 2, 3		34,131	\$16,530				\$16,530	\$150,653	9.1
REN #3	Photovoltaic SFEC Building		127,928	\$61,958				\$61,958	\$457,464	7.4
REN #4	Photovoltaic Barracks Bldgs 170, 173		13,321	\$6,452				\$6,452	\$47,597	7.4
REN #5	Photovoltaic Commissary Bldg 290		208,346	\$100,906				\$100,906	\$760,816	7.5
<b>Totals</b>		<b>4,498</b>	<b>1,702,082</b>	<b>439,890</b>	<b>17,017</b>	<b>261,596</b>	<b>37,400</b>	<b>\$768,672</b>	<b>315,097</b>	<b>0.4</b>

Table 20. Group summary of ECMs.

ECM Category	Report Chapter	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
Building Envelope	3	8,318	0	\$1,251	11	\$157	\$0	\$1,408	\$0	0.0
Central Energy Plant	4	-150,000	0	28,434	4,096	53,000	20,000	101,434	-1,709,000	-16.8
Controls	5	914,510	0	\$137,579	8,953	\$133,306	\$0	\$270,885	\$30,108	0.1
Dining Facilities	6	83,000	0	\$12,487	723	\$16,202	\$0	\$28,689	\$32,400	1.1
HVAC	7	117,600	0	\$17,692	2,788	\$48,913	\$5,000	\$83,229	\$251,562	3.0
Lighting	8	102,928	0	\$20,194	0	\$0	\$2,400	\$22,594	\$52,444	2.3
Miscellaneous	9	0	0	0	0	0	\$0	\$6,054	\$6,054	1.0
Renewables	10	383,726	0	\$185,846	337	\$7,552	\$0	\$193,398	\$1,457,530	7.5
<b>Total</b>		<b>1,460,082</b>	<b>0</b>	<b>\$403,483</b>	<b>16,907</b>	<b>\$259,131</b>	<b>\$27,400</b>	<b>\$707,692</b>	<b>\$121,097</b>	<b>0.2</b>

The **Building Envelope** category contains only one ECM, a cool roofs strategy. The specific savings for the buildings at the installation were not documented, but would be approximately 10 to 15 percent of peak cooling demand and can reduce building energy use by up to 50 percent.

The **Central Energy Plant** category consists of two ECMs, installation of a thermal storage system and an alternative for replacement of the heating distribution system. These two projects result in an avoided capital investment cost of approximately \$1.7 million, thermal savings of 4,096 MMBtu/yr, and maintenance savings of \$20K/yr. Electrical use would increase by 150MWh/yr due to pumping costs. The combined projects then save a little over \$100K/yr with a reduced investment cost of \$1.7 million.

The **Controls** category consists of three ECMs. They would save 914 MWh/yr in electrical use and 8,953 MMBtu/yr in heating costs for a total of \$271K savings/yr. The investment cost of \$30K results in a quick simple payback of 0.1 years.

The **Dining Facilities** ECM group consists of two ECMs. They would save 83,000 KWh/yr in electrical use and 723 MMBtu/yr for a total of \$29K savings/yr. The investment cost of \$32K results in a simple payback of 1.1 years.

The **HVAC** ECM group consists of 10 ECMs. If all HVAC ECMs were implemented, they would save 117,600 KWh/yr in electrical use and 2,788 MMBtu/yr in thermal savings (mostly fuel oil), and \$5K in maintenance savings resulting in a total of \$667K savings/yr. The investment cost of \$252K results in a simple payback of 3.0 years.

The **Lighting** ECM group consists of three ECMs. If all were implemented, they would save 103 MWh/yr of electrical use, and reduce maintenance costs by \$2.4K resulting in total of \$23K savings/yr. The investment cost of \$52 results in a simple payback of 2.3 years.

Five (5) **Renewable** ECMs were identified. If all were implemented, they would save (produce) 384 MWh/yr in electrical use and 337 MMBtu/yr in thermal savings for a total of \$193K savings/yr. The investment cost of \$1.5 million results in a simple payback of 7.5 years.

The Level I analyses of multiple complex systems conducted during the Energy Optimization Assessment are not intended to be (nor should they be) precise. The quantity and quality of the systems improvements identified suggests that significant potential exists.

## **Recommendations**

### **Policy Related Measures**

The cool roofs strategy requires virtually no additional capitol investment. This should be part of the installation design guide.

### **Central Energy Plants**

The two ECMs related to the central energy plants result in \$1.7 million of investment costs and a yearly savings of over \$100K. It is recommended that CEP #2 “Future District Heating System as a Hot Water System” (p 18) be implemented when the distribution system is replaced. CEP #1 “Thermal Storage System” (p 14) should also be considered when any changes to the central cooling system are considered. It should also be considered as a measure to reduce the electrical demand since the electrical distribution system is considered to be very close to its capacity.

### **Low to Moderate Cost Projects**

The eight ECMs summarized in Table 21 were found to have an investment of \$10K or less and result in a simple payback of 1 year or less. All could be implemented as a group for a total of \$32K, save \$47K/yr, and result in a simple payback of just over 6 months. Internal funding (such as SRM) for these projects should be sought.

### **Good Payback and Moderate Investment Projects**

Table 22 lists ECMs with a simple payback of less than 10 years, but which require moderate investments of between \$10K and \$200K. These 16 ECMs together would have annual savings of \$471K at a cost of \$783K million for a simple payback of 1.7 years. Due to their size and complexity, some may need to be developed further by an Energy Optimization Assessment Level II effort.

Table 21. ECMs with investment < \$10K and simple payback < 6 years.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance (\$/yr)	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (\$/yr)	Investment (\$)	Simple Payback (yrs)
		(KWh/yr)	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
CEP #2	Future district heating system as a hot water system	-150,000	0	\$(22,566)	4,096	\$53,000	\$20,000	\$50,434	\$(1,589,000)	-31.5
CEP #1	Thermal storage system	0	0	\$51,000	0	\$-	\$-	\$51,000	\$(120,000)	-2.4
BE #1	Establish a cool roofs strategy (for all re-roofing projects and for new constructions)	8,318	0	\$1,251	11	\$157	\$-	\$1,408	\$-	0.0
CON #3	Consolidate HVAC control systems	0	0	\$-	0	\$-	\$-	\$-	\$-	-
HVAC #10	Re-commission building controls and replace pneumatic controls with DDC	0	0	\$-	0	\$-	\$-	\$-	\$-	-
LI #1	Provide light sensors for spaces with natural light	19,768	0	\$3,878	0	\$-	\$-	\$3,878	\$1,000	0.3
DIN #1	Modify kitchen hoods with end skirts, Bldg 745	41,000	0	\$6,168	235	\$5,266	\$-	\$11,434	\$6,000	0.5
MISC #1	Miscellaneous low/no cost	0	0	\$-	0	\$-	\$-	\$6,054	\$6,054	1.0
LI #3	Install occupancy switches in certain spaces	53,160	0	\$10,430	0	\$-	\$-	\$10,430	\$9,444	0.9
HVAC #6	Enable economizer operation for cooling	90,300	0	\$13,585	0	\$-	\$-	\$13,585	\$10,000	0.7
<b>Totals</b>		<b>62,546</b>	<b>0</b>	<b>\$63,747</b>	<b>4,341</b>	<b>\$58,423</b>	<b>\$20,000</b>	<b>\$148,224</b>	<b>\$(1,676,502)</b>	<b>-11.3</b>

Table 22. ECMs with investments between \$10K and \$200K and simple payback of less than 10 years.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		(KWh/yr0	(kW Demand)	(\$/yr)	(MMBtu/yr)	(\$/yr)				
HVAC #6	Enable Economizer Operation for Cooling	90,300	0	13,585	0	0	0	13,585	10,000	0.7
CON #1	Fix/Replace HVAC Controls	0	0	0	1,247	19,089	0	19,089	12,108	0.6
HVAC #1	Shower Gray Water Heat Recovery	0	0	0	214	3,172	0	3,172	15,000	4.7
CON #2	Reduce HVAC Run Time/Schedule AHUs To Match Building Occu- pancy	914,510	0	137,579	7,706	114,217	0	251,795	18,000	0.1
DIN #2	Variable Flow Kitchen Hoods	42,000	0	6,318	488	10,936	0	17,255	26,400	1.5
HVAC #7	Increase/Decrease Space Temperature Setpoints and Make Them Uniform	27,300	0	4,107	280	4,150	0	8,257	26,600	3.2
HVAC #8	Local Radiator Thermostats to Prevent Overheating.	0	0	0	0	0	0	12,108	26,638	2.2
HVAC #9	Install Heat Recovery From Refrigeration Systems At The Commissary, Building 290	0	0	0	1,294	19,181	0	19,181	36,324	1.9
HVAC #5	Use of Variable Flow Hot and Chilled Water Systems	196,000	0	29,486	0	0	0	29,486	41,000	1.4
REN #1	Solar Wall	0	0	0	337	7,552	0	7,552	41,000	5.4
LI #2	Solar Tubes	30,000	0	5,886	0	0	0	8,286	42,000	5.1
REN #4	Photovoltaic Barracks Buildings 170, 173	13,321	0	6,452	0	0	0	6,452	47,597	7.4
HVAC #2	Gray Water Recovery	0	0	0	0	0	0	11,624	65,000	5.6
HVAC #3	Replace Warm Air Heating System In Vehicle Maintenance Areas with Radiant Heating, Building 2588	0	0	0	1,000	22,410	0	27,410	72,000	2.6
REN #2	Photovoltaic Bldgs 1, 2, 3	34,131	0	16,530	0	0	0	16,530	150,653	9.1
HVAC #4	Improved Moisture Control in Barracks, Building 2102 – 2104 and 2109 - 2111	46,000	0	6,920	110	2,465	37,400	19,385	153,000	7.9
<b>Totals</b>		<b>1,393,562</b>	<b>0</b>	<b>\$226,864</b>	<b>12,676</b>	<b>\$203,173</b>	<b>\$37,400</b>	<b>\$471,168</b>	<b>\$783,319</b>	<b>1.7</b>

### **Good Payback and Significant Investment Projects**

Aside from the central plant ECMs, only a couple of the renewable ECMs require significant investments (over \$200K). Due to their size and complexity, they may need to be developed further by an Energy Optimization Assessment Level II effort, which is geared toward funds appropriation.

### **Level II Analysis Candidates**

Some of the ripest opportunities for savings come from the moderate and high cost ECMs identified. These often require a combination of in-house and outside support.

It is recommended that Caserma Ederle pursue Level II of this Energy Optimization Assessment for Thermal Storage (CEP #1)

### **Thermal Storage**

The rough estimate presented as ECM CEP #1 indicates that a new chilled water plant incorporating a thermal storage tank would be roughly \$120K less than a plant without the thermal storage and the annual electrical cost \$51K less. However, these are rough estimates. The actual pre-design determined in a level II study would determine:

- required cooling load profile based on the types of future buildings and their cooling requirements
- chiller and thermal storage sizing based on required load profile and cooling capacity
- optimal control strategy (When to cool with storage, when to cool with chillers, and when to charge the thermal storage)
- detailed estimates of capital costs of both types of systems (with and without thermal storage)
- detailed estimates of electrical cost savings
- life cycle costs
- economic feasibility of an absorption chiller using waste heat from generators.

## **Photovoltaic**

The potential for photovoltaic (PV) use for electricity generation is good. Estimates presented showed potential for 384 MWh generation/yr, worth \$186K at an estimated investment cost of \$1.4 million. The analysis was thorough; however the following require more in depth analysis:

- investigation of roof structures to ensure the capability of withstanding increased loads and determining the best mechanism for anchoring
- confirmation that the understanding of the rules for payment of PV generated electricity is correct.

Recommendations for the scope of the Level II study can be based on the Level I and demonstration project results. A specific Level II scope could be jointly developed by CERL and U.S. Army Garrison, Vicenza through review and discussion of results documented in this Level I report. The Level II report will include an analysis that “guesses at nothing – measures everything.” CERL and expert consultants would provide guidance and further assistance in identifying a specific Level II scope of work, respective roles, and the most expeditious implementation path. This will begin with a formal review of this (Level I) report, combined with a planning session to organize the Level II program.

## **New Construction**

Since the majority of the existing buildings at Caserma Ederle will be demolished and rebuilt, significant energy savings potential could be realized with minimal additional investment. The basis for doing this is included in newly published (2007-2008) Design Guides. These design guides achieve at least 30 percent savings over a baseline built to the minimum requirements of the ASHRAE Standard 90.1-2004. Types of buildings included are barracks (also called Unaccompanied Enlisted Personnel Housing, or UEPH), trainee barracks, administrative buildings (e.g., a battalion headquarters, a company operation facility), a maintenance facility, a dining facility, a child development center, and an Army reserve center. The recommendations include insulation levels, window U values, allowed infiltration rates, grey water heat recovery, and dedicated outdoor air systems.

## Lessons Learned

An Energy and Process Optimization Assessment (EPOA) is a complex undertaking. There are several key elements that require significant attention to guarantee success:

1. The involvement of key facility personnel who know what the problems are, where they are, and have thought of many solutions.
2. The facility personnel's sense of "ownership" of the ideas, which in turn develops a commitment for implementation.
3. The EPOA focus on site-specific, critical cost issues, which, if solved, will make the greatest possible economic contribution to the installation's facility's bottom-line.

Major cost issues are:

- facility utilization (bottlenecks)
- maintenance and repair optimization (off spec, scrap, rework)
- labor (productivity, planning/scheduling)
- energy (steam, electricity, compressed air)
- waste (air, water, solid, hazardous)
- equipment (outdated or state-of-the-art), etc.

From a cost perspective, facility capacity, materials, and labor utilization are far more significant than energy and environmental concerns. However, all of these issues must be considered together to achieve DOD's mission of military readiness in the most efficient, cost-effective way. The Energy Assessment Protocol developed by CERL in collaboration with a number of government, institutional, and private sector parties is based on the analysis of the information available from literature, training materials, documented and undocumented practical experiences of contributors, and successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities. The protocol addresses both technical and nontechnical, organizational capabilities required to conduct a successful assessment geared to identifying measures that can reduce energy and other operating costs without adversely impacting product quality, safety, morale, or the environment.

Expertise in energy auditing is not an isolated set of skills, methods, or procedures; it requires a combination of skills and procedures from different fields. However, an energy and process audit requires a specific talent for putting together existing ways and procedures to show the overall energy performance of a building and the processes it houses, and how the

energy performance of that building can be improved. A well grounded energy and process audit team should have expertise in the fields of HVAC, structural engineering, and electrical and automation engineering. They should also have a good understanding of production processes.

Most of the knowledge necessary for an energy audit is a part of already existing expertise. Designers, consultants, contractors, and material and equipment suppliers should be familiar with the energy performance of the specific field in which they are experts. Structural designers and consultants should be familiar with heat losses through the building shell and what insulation should be added. Heating and ventilation engineers should be familiar with the energy performance of heating, ventilation, compressed air, and heat recovery systems. Designers of electrical systems should know energy performance of different motors, VFD drives, and lighting systems. An industrial process and energy audit requires knowledge of process engineers specialized in certain processes.

Critical to any energy and process audit team member is the ability to apply a “holistic” approach to the energy sources and sinks in the audited target (installation, building, system, or their elements), and the ability to “step outside the box.” This ability presumes a thorough understanding of the processes performed in the audited building, and of the needs of the end users. For this reason, the end users themselves are important members of the team. It is critical for management, production, operations and maintenance (O&M) staff, energy managers, and on-site contractors to “buy in” to the implementation by participating in the process, sharing their knowledge and expertise, gathering information, and developing ideas.

## Acronyms and Abbreviations

<u>Term</u>	<u>Spellout</u>
AC	air-conditioning
ACS	Army Community Service
ACSIM	Assistant Chief of Staff for Installation Management
AEEG	Atorita per L'Energia Elettrica edil GAS
AEWRS	Army Energy and Water Reporting System
AFN	Air Force Network
AHU	air handling unit
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BBLS	barrels
Btu	British Thermal Unit
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CEP	Central Energy Plant
CERL	Construction Engineering Research Laboratory
CFM	cubic feet per minute
COP	coefficient of performance
DDC	direct digital control
DM	Decree (Italian regulation)
DN	nominal diameter
DPW	Directorate of Public Works
ECBCS	Energy Conservation in Buildings and Community Systems
ECM	Energy Conservation Measure
EEAP	Engineering Energy Analysis Program
EFLH	equivalent full load hours
EMCS	Energy Management Control System
EPAct	Energy Policy Act
EPOA	Energy and Process Optimization Assessment
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESPC	Energy Savings Performance Contract
hp	horsepower
HQIMCOM	(HQ IMCOM) Headquarters, Installation Management Command
HVAC	heating, ventilating, and air-conditioning
IEA	International Energy Agency
IMCOM	Installation Management Command
KCF	1000 cubic feet

<u>Term</u>	<u>Spellout</u>
kWh	kilowatt hour (kWh)
LBNL	Lawrence Berkeley National Laboratory
MILCON	Military Construction
MMBtu	1 million Btus
NSN	National Supply Number
OA	outdoor air
OMB	Office of Management and Budget
PT	physical training
PV	photovoltaic
PX	Post Exchange
RA	return air
RIA	Rock Island Arsenal
RTU	roof top air-handling unit
SA	Supply Air
TR	Technical Report
TV	television
UEPH	Unaccompanied Enlisted Personnel Housing
VA	Virginia
VAV	variable air volume
VFD	variable frequency drive
WWW	World Wide Web

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 17-01-2009		2. REPORT TYPE Final		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Energy Optimization Assessments at U.S. Army Installations: Caserma Ederle Vicenza, Italy				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT	
6. AUTHOR(S) David M. Underwood, Alexander Zhivov, Alfred Woody, Curt Bjork, Dieter Neth, and Roland Ziegler				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Research and Development Center (ERDC) Construction Engineering Research Laboratory (CERL) PO Box 9005, Champaign, IL 61826-9005				8. PERFORMING ORGANIZATION REPORT NUMBER  ERDC/CERL TR-09-3	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Headquarters, Installation Management Command (HQIMCOM) 2511 Jefferson Davis Highway Taylor Bldg., Rm 11E08 Arlington, VA 22202-3926				10. SPONSOR/MONITOR'S ACRONYM(S)  SFIM-OP-P	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT An Energy Optimization Assessment was conducted at Caserma Ederle Vicenza, Italy, as a part of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) initiative to identify energy inefficiencies and wastes and propose energy-related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPA) 2005. The study was conducted by the Energy Team, composed of the Construction Engineering Research Laboratory (ERDC-CERL) researchers and their subject matter experts. The scope of the Annex 46 Energy Optimization Assessment included a Level I study of the central energy plants and associated steam distribution systems providing heat to representative administrative buildings, laundry, dining facilities and other buildings and an analysis of their building envelopes, ventilation air systems, and lighting. The study identified 28 different energy conservation measures (ECMs) that would reduce Caserma Ederle's annual energy use by up to 1,702 MWh/yr in electrical savings, 12,922 MMBtu/yr in thermal energy, and \$37K/yr in maintenance savings for a total of \$769 K/yr of savings.					
15. SUBJECT TERMS Army Installations, cost analysis, energy conservation, energy efficient, Italy, ECM, energy conservation measures					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code)
			SAR	140	